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**FOREWORD**

This document records the system and program requirements for a Space Operations Center as defined by systems analysis studies. The first version of this document, JSC-16244, Requirements for a Space Operations Center, November, 1979, was based on results of a JSC study. The document was revised based on the results of contracted Space Operations Center studies in July of 1981. The present revision incorporated further contracted study results as well as those of further JSC studies. This document is intended as a guide for future study and systems definition for a Space Operations Center and will be periodically revised as new information and increased definition are developed.

This document was prepared by Boeing Aerospace Company as a Contractor Report under Contract NAS9-16151. The requirements included herein have been reviewed and approved by the JSC Space Operations Center program management team.

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	NOTE—These revision descriptions do not include typo corrections, capitalization corrections, etc.		
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	7.304 - Added cryogenic nitrogen storage option		
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**LIST OF ACRONYMS AND ABBREVIATIONS**

<b>AC, ac</b>	<b>Alternating Current</b>
<b>ACS</b>	<b>Attitude Control System</b>
<b>APSM</b>	<b>Automated Power Systems Management</b>
<b>BIT</b>	<b>Built in Test</b>
<b>BITE</b>	<b>Built in Test Equipment</b>
<b>bps</b>	<b>Bits per Second</b>
<b>CF</b>	<b>Construction Facility</b>
<b>CMG</b>	<b>Control Moment Gyro</b>
<b>CRT</b>	<b>Cathode Ray Tube</b>
<b>DDT&amp;E</b>	<b>Design, Development, Test, and Evaluation</b>
<b>DoD</b>	<b>Department of Defense</b>
<b>DC, dc</b>	<b>Direct Current</b>
<b>DT</b>	<b>Docking Tunnel</b>
<b>ECLSS</b>	<b>Environmental Control/Life Support System</b>
<b>EVA</b>	<b>Extravehicular Activity</b>
<b>°F</b>	<b>Degrees Fahrenheit</b>
<b>FM</b>	<b>Frequency Modulation</b>
<b>ftc</b>	<b>Foot candles</b>
<b>FSF</b>	<b>Flight Support Facility</b>
<b>GN&amp;C</b>	<b>Guidance, Navigation and Control</b>
<b>GEO</b>	<b>Geosynchronous Earth Orbit</b>
<b>GPS</b>	<b>Global Positioning System</b>
<b>GPOSE</b>	<b>General Purpose Operational Support Equipment</b>
<b>GSE</b>	<b>Ground Support Equipment</b>
<b>GFE</b>	<b>Government Furnished Equipment</b>
<b>HM</b>	<b>Habitat Module</b>
<b>HMF</b>	<b>Health Maintenance Facility</b>
<b>Hz</b>	<b>Hertz (cycles per second)</b>
<b>ICD</b>	<b>Interface Control Document</b>
<b>ID</b>	<b>Internal Diameter</b>
<b>in</b>	<b>Inches</b>
<b>IOC</b>	<b>Initial Operating Capability</b>
<b>IV</b>	<b>Intravenous</b>
<b>IVA</b>	<b>Intravehicular Activity</b>

JSC	Johnson Space Center
Kg	Kilograms
KM, Km	Kilometers
KSC	Kennedy Space Center
KVA	Kilovolt-Ampere
Kw	Kilowatt
lb	Pounds
lb/ft <sup>3</sup>	Pounds Per Cubic Foot
LEO	Low Earth Orbit
LM	Logistics Module
LRU	Lowest Replaceable Unit
lx	Lumens
m	Meters
min	Minutes
mm	Millimeters
mmHG	Millimeters of Mercury
MMU	Manned Maneuvering Unit
mr	Milliradians
MOTV	Manned Orbit Transfer Vehicle
MTV	Mobile Television
NASOS	National Space Operations System
nm	Nautical Miles
OTV	Orbital Transfer Vehicle
POM	Proximity Operations Module
PM	Pulse Modulation
psia	Pounds Per Square Inch Absolute
RAM	Random Access Memory
RCS	Reaction Control System
RED	Radar Enhancement Device
REM	Reoentgen Equivalent Man
RF	Radio Frequency
RFI	Radio Frequency Interference
SM	Service Module
SF	Storage Facility
SOC	Space Operations Center
STS	Space Transportation System

STDN	Spaceflight Tracking and Data Network
TBD	To Be Determined
TDRSS	Tracking and Data Relay Satellite System
TV	Television
VSS	Versatile Service Stage
Vdc	Volts, Direct Current

## INTRODUCTION

A

This document contains system level requirements for a Space Operations Center (SOC) which is a major element of the National Space Operations System (NASOS). The Space Transportation System (STS) provides the first step in establishment of the NASOS. Moving from ground based operations to space based operations will provide the next major level of capability.

Space based operations will require establishment of an SOC in Low Earth Orbit (LEO) with the companion development of a space based orbit transfer system to provide major increases in capability to high energy orbits. Subsequent increases in capability will require manned access to high inclination and/or geostationary orbits. Permanent manned presence in these orbits may also be required at some future date.

The requirements contained in this document are presented at the system level for an LEO SOC and include those requirements necessary for support of space based orbit transfer systems and other functional systems that operate in conjunction with the SOC.

The approach taken in this document assumes development of SOC in phases with capability provided as mission needs develop. Subsystem requirements will be developed as part of Phase B activities.

## MISSION NEEDS

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The practical use of space over the next 20 years will require the capability to assemble, deploy, control, routinely service, and maintain large and complex commercial and defense space systems. The STS provides the first step in building space operational capabilities; however, due to limitations in orbital stay time, manpower availability, and delivery capability, the STS alone cannot adequately satisfy future space needs.

A permanently manned SOC can provide the required expansion of manned operations capability while at the same time increasing the efficiency and use of the STS.

An SOC, designed to provide incremental capability as needs develop and to exploit STS capabilities, is the essential next step in expansion of the United States space capability. Specifically, there is need to:

**Provide for assembly, construction, service, checkout, launch and recovery of increasingly large and complex payloads in LEO. Such an LEO capability effectively removes limitations which the STS imposes on payload size, weight, and complexity.**

**Provide a base for assembly, service, storage, launch, and recovery of upper stage propulsion systems. Beginning with the currently planned upper stages, the SOC permits matching the transportation system to a variety of payload requirements. Eventual space basing of reusable cryogenic stages will substantially improve access to and reduce cost of geosynchronous space operations.**

**Provide a basis for manned access to high inclination and geostationary orbits. The growth of both commercial and military assets in these orbits demand U.S. dominance and eventually permanent manned occupancy.**

**Provide a manned space presence from which the Department of Defense (DOD) can develop space military capabilities for more efficient conduct of space operations necessary for the National defense.**

**Provide a manned platform wherein long term science and applications research may be conducted.**

**Provide a focus for future NASA space development efforts.**

## **1.000 SOC PROGRAM GENERAL REQUIREMENTS**

**1.001** The Space Operations Center (SOC) program includes the analyses, design, development, and operation of an orbital facility. The SOC is a permanently-manned facility operating in low Earth orbit and used for operational support of space activities such as space construction development, construction and checkout of large space systems, unmanned and manned orbital transfer vehicle operations, on-orbit assembly, launch, recovery, and servicing of space vehicles, and servicing of co-orbiting satellites including the servicing of missions attached to or near the SOC. Resupply shall be via the Space Shuttle. Modules shall be transported to and from low Earth orbit (LEO) internal to the Space Shuttle. If specific elements are not transportable by the Shuttle, they shall be constructed and/or assembled on orbit.

**1.002** The SOC design shall provide phased increases in capability which can be matched to demand for space based services. Each program phase shall establish a significant increase in U.S. manned space capability and shall be justifiable as a stand-alone program if necessary. Modularity in both structure and subsystems shall be emphasized as a means of accomplishing this flexibility and as a means of accommodating budget constraints.

**1.003** Phase I, the initial SOC, shall provide capabilities for the following.

Manned occupancy for short periods between planned Orbiter visits

Space basing and assembly of payloads and expendable orbit transfer systems

Accommodation of space and life science and Earth resources experiments

Accommodation of space processing research

Support of space operations test requirements

**1.004** Phase II, the baseline SOC, shall provide Phase I capabilities plus capabilities for the following.

Continuous manned occupancy

Space basing of reusable orbit transfer systems including propellant storage and transfer

Routine satellite servicing

A basis for development of manned access to all commercially and militarily significant orbits

**1.005** Phase III, the growth SOC, shall provide expanded habitability with reduced logistics requirements, routine manned access to geosynchronous orbit and increased capabilities to perform functions initiated in Phases I and II.

**1.006** Total cost and peak annual funding of the program are primary considerations. Primary emphasis is on minimum cost, including recurring costs, through the initial SOC operational period.

**1.007** The development approach shall minimize the number and cost of test articles, and shall provide for utilization of the Space Shuttle for on-orbit testing.

## 2.000 SPACE FACILITY GENERAL REQUIREMENTS

2.001 Space Shuttle System Payload Accommodation, JSC 07700, Volume XIV, Revision G, change no. 33, dated Sept. 26, 1980, Volume VIII Flight Operations; Volume IX, Ground Operations; and Volume X, Flight and Ground System Specifications shall be the reference for performance and required interface data.

2.002 The SOC shall be designed for operation in a LEO of  $28\ 1/2^\circ$  inclination at an altitude between 370 KM (200 NM) and 450KM (243 NM).

2.003 The SOC shall have the capacity for independent (without resupply) operation with the full crew for a period of at least 90 days in LEO. The full crew is that number of crewmembers the configuration is designed to support at any point in time and may vary from 2 to 12 people over the evolution of the program. A

2.004 At each phase of the on-orbit assembly sequence, the Orbiter and/or SOC onboard crew shall have the capability and resources to checkout and validate the operation of the SOC.

2.005 Solid wastes shall not be dumped into space.

2.006 Dumps or umbilical connections of any gasses or fluids external to the SOC shall not cause any propulsive force, directly impinge on SOC structures or sensors, affect high voltage power supplies or impair the ability of the SOC to conduct its missions.

2.007 "Commonality" is a primary consideration through the study. The various modules shall use common structural assemblies/subassemblies, subsystems, components, and mission hardware as much as practical to reduce program costs.

2.008 The design of all modules and mission hardware during the concept definition phase shall include a 25 percent weight (growth) margin.

2.009 The total launched payload weight of Shuttle-transported modules shall not exceed a maximum of 29,484 kg (65,000 lbs). All payloads as manifested shall fall within shuttle (G. limit) constraints. The Orbiter payload weight for planned landing shall not exceed 14,515 kg (32,000 lbs). Payload weight shall include the SOC module(s), weight growth margin, and all other items chargeable to payload weight. A

2.010 The maximum dimensions of the SOC modules shall be as follows: a. Maximum Diameter--15 feet (4.572 meter.) cylindrical payload thermal and dynamic envelope (see references cited in 2.001 for specific definition of thermal and dynamic envelope). b. Maximum Length--1) For modules delivered by an Orbiter without a docking module - maximum length is 55.0 feet (16.764 meters). Appendages may protrude beyond this length to a maximum of 59.0 feet (17.9832 meters) if the appendage does not interfere with EVA paths. 2) For modules delivered by an Orbiter equipped with a docking module - maximum length is 52.0 feet (15.8496 meters).

2.011 System design shall accommodate variations in SOC configurations due to initial buildup and multiple operations conducted simultaneously such as on-orbit construction, vehicle stage assembly, service, launch, recovery, docking, satellite servicing, and research and applications missions. A



**2.012** All hardware associated with the SOC will be designed and prelaunch operations will be developed so as to require minimum access to the module while in the Orbiter cargo bay.

**2.013** The configuration shall be designed so as not to preclude the removal or replacement of any module.

**2.014** A means of entering any depressurized module that does not require depressurization of the entire SOC shall be provided.

**2.015** "Primary access" routes shall accommodate package volume sizes to 24 in. x 30 in. x 72 in. "Primary access" is defined as a trunk line throughout the SOC connecting all major elements. This access includes docking and berthing subsystems and major mission-oriented equipment. "Secondary access" routes are defined as those that are parallel to or in addition to primary routes such as access to crew quarters, galley, lab, etc.

**A 2.016** The SOC configuration shall provide non-interfering work areas for construction, satellite servicing, flight support, and attached research module operations.

**2.017** The SOC configuration shall provide handling capability and unobstructed paths for all element transfer operations.

**2.018** The SOC configuration shall provide operational flexibility and reasonable avenues for growth.

**A 2.019** The SOC configuration shall provide for a practical buildup sequence; buildup operations shall be accomplished by the Shuttle Orbiter and by SOC elements in place. No unique or specialized equipment shall be necessary.

**2.020** The configuration shall provide moment of inertia symmetry about orbit plane and maximum moment of inertia about axis normal to orbit plane and shall avoid persistent gravity gradient torques. Buildup of stored momentum in the CMG system shall be slow enough that the CMG's can be desaturated by orbit makeup propulsion.

**2.021** The configuration shall provide for subsystem services growth to meet mission needs.

**2.022** The system shall provide a storage and delivery capability for liquid water and hydrazine and gaseous  $N_2$  and  $O_2$  to support the ECLS and propulsion subsystems. The anticipated storage systems will support the delivery of atmospheric gases, hydrazine, water makeup as required, and orbit makeup propulsion fluids.

**2.023** The design of the fluid storage system will be optimized to meet the design requirements of the systems (i.e., pressure, temperature, and configuration). Where storage of cryogenic fluids is required for compactness, subcritical pressures will be the design goal. Where liquefied gases are required (i.e., experiments, propulsion, etc.), internal components will be employed to meet the low pressure, low weight requirements.

**2.024** The systems design of the fluid storage system shall encompass safety and reliability margins necessary to prevent single point failures and provide emergency fluid provisions to life support systems.

**2.025** The SOC shall be operational when it has the capability of being continuously manned. To be operational, the SOC shall have capability for environmental control and life support, electrical power, stabilization and control, guidance and navigation, communications and tracking, thermal control, and data management for a period of 90 days without resupply (with the exceptions noted in requirement 2.102).

A

**2.026** The SOC elements shall be capable of maintaining orbital altitude and attitude in an unmanned mode during base buildup (via ground control) and in the event that the SOC must be evacuated (also see 2.030 and 2.031).

A

**2.027** Initial module berthing or module transfer between ports shall be done only when the Shuttle is docked to the SOC.

**2.028** The first service module to be orbited shall provide the following communications:

- a. telemetry/commands (uplink and downlink);
- b. metric tracking (GPS);
- c. and when manned, duplex voice links;
- d. communications distribution interfaces.

Subsequent attached modules can rely on the first module for these communications.

**2.029** The SOC shall provide any necessary interface capability with the Orbiter subsystems during orbiter-tended operations (during base buildup).

**2.030** The SOC shall normally fly at an altitude such that its orbit lifetime is at least 90 days without orbit makeup. The orbit makeup propellant quantity onboard shall be normally maintained at a level which is sufficient for 90 days orbit maintenance at the designated altitude. Any time these conditions are not satisfied, all necessary steps to correct the situation will be taken.

**2.031** The measure of last resort to prevent uncontrolled deorbit shall be a controlled deorbit. Accordingly, sufficient reserve capacity in the propulsion system shall always be maintained to accomplish a deorbit from 200 KM. Reserve capacity includes operable thrusters as well as deorbit propellant. The required delta V is approximately 42m/sec. This delta V must be delivered in 20 minutes or less.

**2.032** The design shall permit utilization of element and subsystems in high inclination and geosynchronous orbits.

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**2.033** Design for a 10-year operational life with maintenance.

A

**2.100 SAFETY REQUIREMENTS**

**2.101** For emergency conditions, the following capabilities shall be provided:

- a. Rescue by the Orbiter within 504 hours. (21 days)
- b. Isolation of any module containing hazardous/toxic materials from the remainder of the SOC within 30 seconds.
- c. Rescue of up to 12 crewmen from the SOC.

**2.102** In the event of a complete functional loss of any one module during the initial buildup phases, the SOC shall maintain itself in a stable attitude and orbit for a period of 21 days for a 4 crew operational capability and 90 days, beginning at any point in the resupply cycle, for 8 crew and larger capability. Habitable conditions such as atmosphere, food, water, waste management, health care, personal hygiene, sleeping provisions, communications, and command/control shall be provided in the remaining modules during these periods.

**2.103** In the event of critical onboard subsystems failure, SOC subsystems shall be designed to minimize risk of loss of modules, injury to the crew or damage to the Orbiter and other vehicles (fail operational/fail safe).

**2.104** All of the systems that incorporate an automated fail operational capability shall be designed to provide crew notification and data management system cognizance of the malfunction until the anomaly has been corrected.

**2.105** The allowable radiation limits for the crew are listed below:

**Radiation Exposure Limits and Exposure Rates Constraints for Unit Reference Risk**

Constraints in Rem	(Rem) Bone Marrow (5 cm)	Skin (0.1 mm)	Eye (3 mm)	Testes <sup>2</sup>
1 yr avg daily rate	0.2	0.6	0.3	0.1
30-day maximum	25	75	37	13
Quarterly maximum <sup>1</sup>	35	105	52	18
Yearly maximum	75	225	112	38
Career limit	400	1200	600	200

1. May be allowed for two consecutive quarters followed by six months of restriction from further exposure to maintain yearly limit.
2. These dose and dose rate limits are applicable only where the possibility of oligospermia and temporary infertility are to be avoided. For most manned space flights, the allowable exposure accumulation to the Germinal Epithelium (3 cm) will be the subject of a risk/gain decision for particular program, mission, and individuals concerned.

These exposure limits and exposure rate constraints apply to all sources of radiation exposure. In making trade-offs between man-made and natural sources of radiation, adequate allowance must be made for the contingency of unexpected exposure.

**2.106** Radiation doses which affect personnel safety must be considered from all sources, including natural environment, external isotope and reactor sources, if any, electromagnetic, and solar cosmic radiation.

**2.107** No single malfunction or credible combination of malfunctions and/or accidents shall result in the potential of injury to personnel or to crew abandonment of the SOC.

**2.108** The SOC shall, in the following order of preference: (1) be designed to eliminate hazards by appropriate design measures; (2) prevent hazards through use of safety devices or features; (3) control hazards through use of warning devices, special procedures, and emergency protection subsystems such as pressure suits, portable oxygen supply, or escape balls.

**2.109** The SOC shall provide the capability for performing critical functions at a nominal level with any single component failed or with any portion of a subsystem inactivated for maintenance.

**2.110** The SOC shall provide the capability to perform critical functions at a reduced level with any credible combination of two component failures, or with any credible combination of a portion of a subsystem inactivated for maintenance and failure of a component in the remaining portion of the subsystem.

**2.111** Capability shall be provided for performing critical functions at any emergency level until the affected function can be restored or the crew returned to Earth:

- a. With any one module inactivated or isolated and vacated due to a malfunction or accident.
- b. With any credible combination of a subsystem inactivated as a result of an accident and a portion of a redundant or back-up system inoperative.

**2.112** For those malfunctions which may result in time-critical emergencies, provision shall be made for the automatic switching to a safe mode of operation and for caution and warning of crew members. As a design goal, automated safing and reconfiguration shall be adequate for up to 8 hours prior to crew attention.

**2.113** Capability shall be provided for extinguishing any fire in the most severe oxidizing environment\* prior to failure of primary structural elements. Interior walls and secondary structure shall be self-extinguishing.

**2.114** All continuous nonmetallic materials shall be self-extinguishing in the most severe oxidizing environment\* to which they will be exposed. Means shall be provided for fire resistant storage of medical supplies, maintenance supplies, food, tissue, clothing, trash, and for other non-self-extinguishing items, where they are in use.

**2.115** Materials used in the habitable areas shall not outgas toxic constituents in the lowest pressure environments to which they will be exposed.

\*The "most severe oxidizing environment" shall be consistent with qualification of materials and equipment, e.g., 30% oxygen partial pressure for cabin atmosphere.

**2.116** Two or more entry/egress paths sized for an EVA-suited crewman with emergency lighting shall be provided to and from every pressure isolable volume (except for the Logistics Modules). The two paths shall be separated by airtight partition, or shall be at least ten feet apart, and shall lead to an area in which the crew can survive until shuttle rescue or resupply. In the case of a Logistics Module or Airlock Module, an acceptable means to rescue crewmen isolated in these modules would be to deberth the module and move it to another berthing port. A design goal shall be to provide alternate escape routes that do not terminate into a common module area.

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**2.117** Provisions shall be made for detecting, containing (i.e., confining), and controlling (i.e., restoring to a safe condition) emergencies such as fires, toxic contamination, depressurization, structural damage, etc.

**2.118** Potentially explosive containers such as high pressure or volatile gas storage containers shall be placed outside of and as remotely as possible from living and operating quarters. Wherever possible, the containers shall be isolated and protected so that failure of one will not propagate to others.

**2.119** Redundant equipment, lines, cables, and utility runs which are critical for safety of personnel or continued facility operation shall be routed in separate compartments (i.e., separated by a structural wall) or protected against fire, smoke, contamination, overpressurization, and shrapnel.

**2.120** As a goal, all walls, bulkheads, hatches, and seals whose integrity is required to maintain pressurization shall be accessible for inspection, maintenance, or repair by shirt-sleeved crewmen.

**2.121** Inspection, maintenance, and repair of docking assembly mechanisms by shirtsleeved crewmen shall be provided.

**2.122** Deployment and initiation of operations considered hazardous shall be checked out from a safe location before exposing crewmen to potential hazards.

**2.123** All EVA shall be conducted either using the "buddy" system or within continuous visual contact via direct vision through a window or via closed circuit television.

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**2.124** Provisions shall be made to return crewmen to the SOC who are incapacitated while performing EVA.

**2.125** Provisions shall be made for the containment and/or disposal of toxic contaminants.

**2.126** Hazardous or toxic fluid storage, conduits, and interconnects between modules shall be external to the pressurized volume. An exception may be made for flammable but non-toxic gases where the maximum possible quantity released by a leak cannot result in a flammable mixture.

**2.127** All cabin pressure vessels shall be designed to leak-before-rupture criteria. A cabin wall puncture due to accident or collision shall not result in rupture.

**2.128** The SOC (during buildup/premanning) shall be capable of being manned (shirtsleeve or IVA) for performance of maintenance and station assembly tasks following any one component failure.

**2.129** Equipment or materials sensitive to contamination shall be handled in a controlled environment. Fluids and materials shall be compatible with the combined environment in which they are employed. Process specifications shall be formulated to prescribed handling and application methods.

**2.130** Conservative factors of safety shall be provided where critical single failure point modes of operation cannot be eliminated (pressure vessels, pressure lines, valves, etc.).

**Pressurized lines and fittings**

<u>Size (I.D.) "</u>	<u>Ult. Factor of Safety</u>
1.5	4.0
1.5	2.0

Valves, Regulators, other pressurized components shall have an ultimate factor of safety of 2.5.

**2.131** Subsystem or component failures shall not propagate sequentially. Equipment shall be designed to be fail operational/fail safe.

**2.132** The SOC shall have capability to provide crew warning of hazardous conditions and provisions for corrective action, emergency crew egress/escape or rescue, or mission termination.

**2.133** Provisions shall be made to prevent hazardous accumulations of gases or liquids in SOC (i.e., toxic, explosive, flammable, or corrosive). Detection of hazardous gases shall be required in critical areas and closed compartments to insure no hazardous conditions exist.

**2.134** SOC drains, vents, and exhaust ports shall prevent exhaust fluids, gases, or flames from creating hazards to personnel, vehicle, or equipment.

**2.135** SOC subsystems shall be designed to prevent inadvertent or accidental activation or deactivation of safety-critical functions or equipment which would be hazardous to personnel or SOC.

**2.136** SOC batteries shall be isolated and/or provided with safety venting systems and/or explosion protection.

**2.137** Pressure vessels shall be protected against overpressurization or underpressurization which could be hazardous to personnel or SOC.

## **2.200 MAINTAINABILITY REQUIREMENTS**

**2.201** Maintenance and repair shall be performed on-orbit to the LRU level.

**2.202** Onboard systems will be provided for checkout, monitoring, warning, and fault isolation to a level consistent with safety and with the in-orbit maintenance and repair approach selected. Emergency control and repair of failure or damage will also be provided. As a goal, the overall operations will not be substantially degraded by selected repair modes.

**2.203** Individual subsystems in the SOC shall provide for fault isolation and subsystem checkout. Onboard checkout shall be automated through the data management system and fault isolation and subsystem checkout will be performed inflight.

**2.204** Subsystem design shall include a built-in-test (BIT) capability to facilitate detection and reporting of functional discrepancies. As a minimum, this BIT capability shall enable failure detection at a functional path level inflight along with fault isolation. BIT will be implemented by utilizing continuously-monitoring built-in-test equipment (BITE), self-test circuitry (self-test), and by providing adequate test point information at the electrical interfaces. BITE shall be provided for all time-critical equipment.

**2.205** Subsystems equipment shall be removable or replaceable by using installation-handling devices and an onboard tool kit. The interconnecting plumbing and wire runs shall have suitable attachment, length, and mounting characteristics to facilitate removal/replacement.

**2.206** Onboard checkout shall be used to isolate faults to specific modularized subsystems. These subsystems, similar to the line-replaceable units in the Orbiter, may be further subdivided into submodule units, which can be isolated and replaced either as an LRU or at the workbench level of maintenance.

**2.207** Data for long trend analysis for failure prediction shall be provided through the data management system for transmission to the ground. Advisory information shall be provided to the crew for possible unscheduled maintenance.

**2.208** Critical subsystems shall be designed to fail-operational. Non-critical systems shall be designed to fail-operational or fail-safe such that maintenance and repair can be scheduled within the constraints of other high priority crew activities.

**2.209** As a design goal, all failures or damage (including structural) shall be repairable. Failure or damage events with an expected occurrence rate less than  $10^{-2}$  per year shall be considered "exceptional" and may employ exceptional repair measures such as temporary interruption of normal SOC operations or temporary depressurizational deactivation of a module. The aggregate expectation of any exceptional repair or maintenance activity due to all causes shall be less than  $10^{-1}$  per year.

**2.210** All critical life limited components and subsystems shall be designed to allow ground and on-orbit inspection/monitoring.

**2.211** Loss of redundancy for critical functions shall be detectable automatically by the data management subsystem and the crew via caution and warning system alert signals.

## 2.300 RELIABILITY REQUIREMENTS

**2.301** The redundancy requirements for all SOC subsystems (except primary structure and pressure vessels) shall be established on an individual subsystem basis, but shall not be less than fail-safe during all mission phases.

The items not meeting the fail-safe redundancy requirements shall be identified in an individual SOC critical items list.

The primary structure and pressure vessels subsystems shall be designed to preclude failure by use of adequate design safety factors, relief provisions, fracture control, or safe life and/or fail-safe characteristics.

**2.302** System and subsystem reliability shall be high enough that maintenance activities do not place excessive demands on crew time. As a provisional design goal, the crew time devoted to all scheduled maintenance and repair activities will not exceed an average of  $\frac{1}{2}$  person-shift per day.

**2.303** System and subsystem reliability shall be high enough that equipment outages, spares storage, and spares resupply do not impose significant penalties on SOC operations. Provisional goals are:

- o Interruption of routine operations due to scheduled equipment maintenance shall be 0% of the time
- o Onboard spares volume (excludes mission-related spares such as OTV spares): less than 10% of the volume of SOC subsystems and equipment
- o Spares resupply mass & volume: less than 10% of consumables resupply mass & volume.

**2.304** Critical functions (i.e. those related to crew safety or SOC permanence) shall have backup or work around modes whenever possible.

**2.305** Redundant functional paths or subsystems shall be designed so that their operational status can be verified without removal of LRU's. In addition, these redundant functional paths of subsystems shall be designed so that their operational status can be verified in flight to the maximum extent possible. As a minimum, these shall provide capability for redundancy management in the event of a malfunction of a functional path and shall provide information to the crew regarding redundancy status of the affected system sufficient to determine if a failure occurred. Critical redundant items whose failure cannot be detected during flight shall be identified in the individual SOC critical items list. Redundancies within a functional path shall be so designed that their operational status can be verified prior to each installation into the vehicle.

**2.306** Alternate or redundant means of performing a critical function shall be physically separated or protected at least to the extent of separating the first means from the second means, such that an event which causes the loss of one means of performing the function will not result in the loss of alternate or redundant means.

**2.307** Redundant components susceptible to similar contamination or environmental failure causes such as shock, vibration, acceleration or heat loads shall be physically oriented or separated to reduce the chance of multiple failure from the same cause(s).



**2.308** Isolation of anomalies or critical functions shall be provided such that a faulty subsystem element can be deactivated either automatically or manually without disrupting or interrupting alternate or redundant functional paths. Capability to fault-isolate to the line replaceable unit or group of units without disconnections or use of carry-on equipment, shall be provided.

**2.309** Provisions shall be made for arming explosive devices as near to the time of expected use as is feasible. Provisions shall be made to promptly disarm explosive devices when no longer needed.

**3.000 SERVICE MODULES**

**3.001** A Service Module shall be the first SOC module delivered to LEO.

**3.002** The Service Modules shall be pressurizable modules.

**3.003** Each of the Service Modules shall incorporate at least eight berthing ports and 1 docking port. The docking port shall be located so that the Orbiter can dock or berth to this position with tail clearance under maximum docking misalignment conditions (6° pitch).

**3.004** The following elements/subsystems shall be attached to the exterior of the service modules:

- a. Solar array boom (with antennas/electronics, RCS, electronics radiators, and solar array attached)
- b. O<sub>2</sub> storage
- c. N<sub>2</sub> storage
- d. Hydrazine storage
- e. Battery storage
- f. Handling fixtures

**3.005** The elements/subsystems to be attached to the interior of the service module shall take into account the habitability requirements cited in Requirement 2.102.

**3.006** The service modules shall be designed with habitability provisions such that permanently-manned SOC operations with up to four crew can be initiated with only the two service modules in orbit.

**A**

## **4.000 HABITAT MODULES**

### **4.100 General Requirements**

**4.101** The interior design/interior architecture of the SOC—especially the Habitat Modules—shall utilize the principles of architecture and interior design to maximize the habitability (livability) of the interior space. Such principles shall be applied in the interior layout and arrangement and the detail design, in all aspects, to increase the apparent size of the spaces, provide sensory stimulus, spatial variety, kinesthetic involvement, etc.

**4.102** The SOC shall have windows in all Habitat Modules that provide viewing of both space and Earth.

**4.103** The SOC shall provide private sleeping quarters for the nominal crew of eight crewmen.

**4.104** The sleeping quarters provided for each of the normal SOC crew shall be basically equal, though not necessarily identical.

**4.105** The layout, furnishings, color schemes, lighting, air conditioning, noise, contamination and odor control, traffic flow provisions, and variety of public and private spaces shall be consistent with good architectural/spacecraft design.

**4.106** Personal hygiene system—The SOC will provide adequate, private facilities for washing in each Habitat Module. A shower shall be provided.

**4.107** Waste management system—The SOC will provide adequate, private facilities for feces, urine and vomitus collection and disposal in each Habitat Module.

**4.108** Food system—Dining facilities shall provide for feeding at least four crewpersons (and a maximum of eight) at one sitting.

A food system will be provided which optimizes crew acceptability and palatability. To accomplish this, the system shall include the possibility of incorporating frozen, retorted, and dehydrated food items. Bulk packaging of food items to support cafeteria style food service will be provided. This will be supplemented with a fast food type operation for snack and lunch items, including beverages, and be available on a continuous basis. Ease of food preparation and cleanup is essential.

The following equipment is required:

- a. Freezers ( $-10^{\circ}\text{F}$ ) and refrigerators ( $40^{\circ}\text{F}$ ).
- b. Oven.
- c. Dishwasher.
- d. Food preparation and serving equipment, i.e., trays, tables, dispensers for beverages, etc.
- e. Capability for growing fresh salad greens (should be considered but not necessary for initial SOC).

f. **Trash management**—A trash compactor shall be provided. This will be used for compacting food-related and other trash. Suitable packaging and storage for compacted waste shall be provided. Disinfecting and bacteria retarding must be considered.

g. **Hot water supply** - 140°F

h. **Cold water supply** - 45°F

i. **Capability for baking bread items** should be considered but is not a requirement for the operational SOC.

**4.109 Sleeping quarters**—Individual private sleeping quarters shall be provided for each crewmember. These facilities will be sized to allow doubling up during crew changeover or contingency operations. Adequate personal stowage shall be provided in the quarters for the crewmember's personal clothing and equipment.

**4.110 Exercise/recreational facilities**—Provide adequate exercise equipment facilities to maintain the physical well being of all crewmembers. Recreational facilities for off-duty activities shall be provided.

**4.111 Housekeeping/laundry system**—Each Habitat Module shall provide adequate equipment and waste stowage volume to provide for the cleanliness of the area. Vacuum cleaners and cleansing materials will be provided to permit the crewmembers to maintain the necessary levels of cleanliness in the habitability module. Provisions will be made to provide for cleansing which includes microbial control of all pressurized volumes. Laundry facilities will be provided for washing and drying clothing.

**4.112 Stowage system**—In general, the stowage system shall provide adequate stowage volume for all necessary items, provisions, consumables, spares, etc., necessary to the operation of the SOC and its functions. The various items shall be stowed as convenient to their use location as is practical. The capability of monitoring the stowage inventory and use rate shall be provided.

**4.113 Command control center**—The SOC shall have command/control facilities adequate to perform the mission functions of the SOC. Adequate backup facilities shall be provided for contingency operations. Two work stations shall be located in each command center. The command center shall be located such that direct view over the top of an adjacent module can be provided for viewing outside operations.

**4.114 Reserved.**

**4.115 Noise**—The SOC shall provide noise attenuation to maintain noise levels consistent with design criteria as specified in NASA SP-3006 "Bioastronautics Handbook".

**4.116 Minimal accommodation to be provided in each Habitat module for degraded or emergency conditions** shall include the following:

- a. sleep restraints for eight people
- b. contingency rations (see next requirement)
- c. full (drinking and food reconstitution) water ration
- d. exercise equipment
- e. health care
- f. working provisions (doing repair work)—regular work can be suspended until emergency or degraded condition is solved.

- g. waste management
- h. personal hygiene (except showers)

**4.117 Food management—**

**a. Normal rations**

- . 3.6 lb/man-day of shelf-stable food (includes food, water in the food, and the packaging)
- . 1.0 lb/man-day of frozen food (includes the food, water in food, and the packaging).
- . 5.5 lbs of water/man-day (1.5 lb man-day for drinking, 4.0 lb/man-day for food rehydration)
- . 10 lb/ft<sup>3</sup> for refrigerated/frozen food
- . 14 lb/ft<sup>3</sup> for shelf-stored food

**b. Contingency rations**

- . Contingency rations shall be the same food as used for normal rations, only less quantity per person per day will be allocated (see below).
- . 2.06 lb/man-day (shelf stable) for 90 days
- . 5.5 lbs of water/man-day

c. Food storage shall be distributed between the pressurized modules such that there will always be sufficient contingency food available if one food storage location is evacuated and resupply is not available for 90 days. Food stored in the vacated module shall not be considered to be available.

**4.118** Floors, walls, and ceilings shall primarily be smooth surfaced with a minimum of cracks and crevices to provide a good working surface for suction-cup shoes and to support ease of cleaning and to reduce dirt and microbial buildup.

**4.119** The Habitat Module shall accommodate experimental equipment and experiments on a space-available basis. Such equipment and experiments shall conform to all SOC safety requirements.

## **4.200 HEALTH MAINTENANCE**

**4.201 Crew medical training**—At least one crewman shall have extensive medical training, or actually be a physician. At least a second crewman should have 100 hours of medical training.

**4.202 Medical diagnosis**—The SOC health care facility shall have appropriate diagnostic equipment and a programmed medical diagnosis logic scheme. The interface would be accomplished on a CRT display and the program will include a broad spectrum of the most anticipated medical conditions.

**4.203 Medical treatment**—SOC will have a program treatment logic scheme which will follow the diagnosis. These treatment modalities will cover the broad spectrum of the most common treatment approaches. Drugs and medications will be similar to the Space Shuttle Medical Systems (SOMS-A and SOMS-B) but with appropriate changes in medical supplies and equipment based on anticipated medical conditions and requirements.

**4.204 Dental treatment**—The dental treatment capability will be similar to that which was used in Skylab. That capability was all inclusive for dental problems. The prime medical crewman will need training in extractions, temporary fillings, and dental pain suppression.

**4.205 Surgery**—Provide facilities for the treatment of fractures, and minor trauma and stabilization of patients with major trauma for extended periods of time. The ability to administer general anesthesia will be required. In addition, surgery on SOC will include incision and drainage of a wound and other procedures which do not require an elaborate sterile field. Provisions will be implemented to contain and control body fluids, including blood, urine, feces, and vomitus. A method, and the equipment to sterilize surgical instruments, should also be provided.

**4.206 Stabilization**—A crewman who becomes ill or injured may have to be transferred back to Earth for final treatment. While he waits for transportation, he may require medical monitoring and stabilization with a variety of life support systems. Such systems should be included in the SOC health care facility and may be located in the treatment area.

**4.207 Monitoring**—The SOC will have equipment to monitor vital signs, and will have the capability to transmit cardiac rhythm to the ground as needed.

**4.208 Communications**—A downlink system of communications will include image transmission so that the onboard medical crewmen may show images of an injured crewman, microscope slides, or X-ray images while he is in consultation with the ground physician.

**4.209 Equipment maintenance**—During the course of an extended mission such as SOC, there will undoubtedly be equipment failures and instances where it becomes desirable to change or add to the equipment onboard. It is expected that a crewman will be trained in making necessary repairs and maintenance on medical equipment. Equipment should be self-diagnosing via microprocessors and modular construction.

**4.210 Medical records and data—**The Health Maintenance Facility shall contain computer storage capability for biomedical data. Such a computer will provide immediate accessibility of medical records on each of the crewmen. In addition, it will serve as input by the medical crewmen of all significant physiological data obtained on the crewmen on a daily basis. This computer will also receive and analyze data obtained from any biomedical experimentation being carried out during the mission. Downlink and uplink communications will be provided.

**4.211 The following medical equipment shall be provided:**

- a. **Computer—**The purpose of the computer will be for storage of diagnostic and treatment program, medical records, and treatment data. Data retrieval will be accomplished by CRT or similar terminal onboard or from the ground. Hard copy output shall be available at the discretion of the operator. It is possible to share a computer with other onboard systems if the computer will be available at any time, and a terminal is located in the HMF. Distributed processing shall be considered to avoid single point failures.
- b. **Diagnostic equipment—**
  - 1. Portable diagnostic imaging device (e.g., X-rays, computerized tomography, radionuclide imaging, ultrasound)
  - 2. Microscope—(Research grade medical)
  - 3. State-of-the-art clinical laboratory equipment for analyses of microbiology, serology, hematology, clinical chemistry, and immunology
- c. **Medications—**
- d. **Surgical equipment—**(specific instruments TBD)
- e. **Dental equipment—**(similar to the equipment used in Skylab Dental Kit)
- f. **Electrodiagnostic and monitoring equipment—**This will include EEG, EMG, ENG and EKG leads, an automatic blood pressure recorder, and temperature probes.
- g. **Medical suction device—**(for the aspiration of blood and body fluids)
- h. **Respirator—**synchronized
- i. **Defibrillator—**
- j. **Airway maintenance equipment—**(laryngoscope, endotracheal tubes, and adaptors for the respirator.) (The suction cup apparatus will be used in support of airway maintenance.)
- k. **Restraint systems—**(Special quick-release restraint systems. Such restraints would be used by both a treating medical crewman as well as on the injured or ill crewman.)

- l. IV fluid system—(need a nominal amount of approximately 20 liters of intravenous solution. In addition, there will be need for 2 or 3 devices which would be used in the effective administration of IV fluids in weightlessness)
- m. Laminar flow workbench—(to examine growth plates, plate microbial specimens, obtain blood and urine specimens after they have been centrifuged, etc.)
- n. Cardiovascular Countermeasures—

**4.212** Equipment and procedures shall be provided for environmental monitoring of the following:

- a. Air samples for anomalies and toxic substances
- b. Light, noise, and heat
- c. Radiation from natural sources and from radioactive substances used in medical diagnostic procedures
- d. Trade gasses
- e. Radiological waste
- f. Microbiological organism buildup

**4.213** Provisions shall be made for providing a low noise environment in the HMF to facilitate acoustically coupled diagnostic procedures, e.g. auscultation. Sound level is not to exceed NC35.\*

**4.214** Equipment and procedures shall be provided for maintenance of crew physical fitness quantifiably.

**4.215** Biologically contaminated waste material shall be disinfected as close as possible to its source prior to storage, processing, or disposal.

**4.216** Provisions shall be made to utilize one of the EVA air locks as a hyperbaric chamber for treating decompression sickness. This chamber shall be capable of being pressurized to 45 psi. This chamber must be large enough for the injured crewman, a medical attendant, and suitable monitoring equipment.

\* Noise Criteria Curve 35, Modified - BERANDIL, 1960.



**5.000 LOGISTICS MODULES**

**5.001** The LM shall berth to dedicated berthing ports.

**5.002** The LM shall incorporate provisions for transporting and storing the following items:

o Shelf stable food	192 ft <sup>3</sup>
o Frozen food	40 ft <sup>3</sup>
o Personal gear, clothing, etc.	104 ft <sup>3</sup>
o ECLS supplies	88.8 ft <sup>3</sup>
o EVA supplies	105.2 ft <sup>3</sup>
o hydrazine	242 ft <sup>3</sup>
o ship stores, maintenance, housekeeping supplies	68.4 ft <sup>3</sup>
o SOC spares	25 ft <sup>3</sup>
o water	148.5 ft <sup>3</sup>

**5.003** The water and hydrazine shall be stored in an unpressurized area. All other items must be contained in a pressurizable volume.

**5.004** Umbilical provisions must be incorporated for transferring the water and hydrazine into the SOC systems.

**5.005** Transfer of all items stowed in the pressurized volume shall be via hand-carrying.

**5.006** In the event a crewman is isolated in a LM due to the isolation of a SM, a suitable rescue mode would be to move the LM to another berthing port.

**5.007** A portable oxygen supply and a flashlight shall be provided for use in the emergency mode described in 5.006.

**6.000 DOCKING TUNNEL**

- 6.001** Shall be structurally similar to the Service Modules.
- 6.002** Provide an IVA path between the 2 Habitat Modules.
- 6.003** Provide 2 Orbiter docking ports.
- 6.004** Provide structural attachment points for pliers and tracks.
- 6.005** Provide 7 berthing ports.
- 6.006** Provide a bench test facility within the pressurized volume, for subsystems servicing.
- 6.007** Provide 2 umbilical stations.
- 6.008** Provide a cherrypicker recharge station.
- 6.009** Provide 2 stations for connecting portable external lighting systems.
- 6.010** Provide thermal ventilation units.
- 6.011** Provide an intercomm station.

**7.000 SUBSYSTEM REQUIREMENTS****7.100 STRUCTURES**

**7.101** All major load-carrying structures of the structural subsystems shall be designed to a safe life of a minimum ten years in orbit. Life limitations shall be identified.

**7.102** As a goal, fail-safe design concepts shall be applied to all critical structure so that failure of a single structural member shall not degrade the strength or stiffness of the structure to the extent that the crew is in immediate jeopardy.

**7.103** The structure shall be designed to resist damage resulting from accidental impact during crew activities.

**7.104** The design of the pressure shell and other critical structural members shall facilitate maintenance and repair. This includes the use of smooth surfaces, minimum crevices, and general accessibility.

**7.105** Safety factors used for structural design shall be consistent with those currently used for manned operations.

**Strength**

<b>Ultimate</b>	A factor of safety of 1.5 shall be applied to the ultimate strength for unpressurized structure and 2.0 for pressurized structure.
<b>Yield</b>	A factor of safety of 1.1 shall be applied to the yield strength for unpressurized structure and 1.5 for pressurized structure.
<b>Creep-rupture</b>	The creep-rupture design life of all pressure vessels shall be greater than 50 years.

**Fail Safe Structure**

The structure shall be designed so that any credible failure mode in the structure shall not result in a catastrophic failure. Specifically, cabin pressure vessels shall be designed to leak-before-rupture criteria, and shall not rupture as a result of accidents or collision.

**Windows**

<b>Ultimate</b>	Factor of safety greater than 3.0 (never less than 1.5 at any time during life).
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**Redundant Panes.**

**7.106** Meteoroid and debris protection shall be provided by the SOC design consistent with the meteoroid flux given in TM X-53865, second edition, dated August 1970, and the 1980 extrapolated man-made debris flux at the selected SOC altitude.

**7.107** Dynamic isolation is required for rotating machinery.

## 7.200 ELECTRICAL POWER

**7.201** Electrical energy may be provided by photovoltaic solar arrays, fuel cells, and batteries. Minimum average load electrical power requirements is 50 kw at the load bus, averaged over a 24-hour period. Energy storage for eclipsed (dark side) power supply shall be by batteries and/or regenerative fuel cells or energy-momentum wheels whose energy is restored from the solar arrays during light-side operation.

**7.202** As a goal, solar cell arrays shall have a clear unobstructed view of the sun to preclude partial shadowing of their surfaces. The arrays shall be designed to provide adequate power under any partially-shadowed conditions that cannot reasonably be avoided and to preclude shadow-induced damage.

**7.203** Emergency power shall be provided for pressurizable volumes for crew survival up to a minimum of 504 hours in LEO.

**7.204** The selected EPS shall accommodate the capability for growth including both configuration compatibility and electrical compatibility.

**7.205** The EPS shall, as a whole, have a maintained lifetime of not less than ten years; however, elements of the EPS may be replaced in total or in modular form for maintenance or for growth. As a design goal, during this maintenance or uprating period, the required electrical power levels will be sustained without interruption.

**7.206** The electrical subsystem shall provide circuit protection devices for all power equipment and station distribution wiring. Redundant circuits shall be isolated. Switching to supply load busses from any source available shall be included.

**7.207** Standard electrical interfaces shall be provided for power transfer between modules and other attachable elements requiring a power transfer interface with the SOC.

**7.208** The electrical subsystem shall provide both dc and ac service to users (mission hardware, transportation systems, etc.) as follows:

<u>DC Power</u>	- 120Vdc on solar array voltage, 28Vdc regulated, TBD voltage for battery charging.
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<u>AC Power</u>	- 115/200 Vac, 3-phase, 400 Hz, TBD KVA.
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**7.209** Conversion devices shall be provided for the following:

Regulators	- Convert 120Vdc to regulated 28Vdc nominal.
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Battery Chargers	- Convert 120Vdc to TBD output
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Inverters	- Invert 120Vdc or 28Vdc to 115/200, 3-phase, 400 Hz, TBD power.
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**7.210** Controls shall be provided for main connect/disconnect to solar arrays, dc and ac loads, and redundancy. Controls shall limit/minimize transients and may be performed by a computer.

**7.211** Compartment gases and pressures shall not be hazardous to the electrical power system components so as to cause corrosion, deterioration, or corona. The electrical system shall be designed to be compatible with the SOC environments and outgassing products.

**7.212** Critical loads shall be provided with emergency power in the event of a power system failure. Emergency batteries shall be employed to maintain critical lighting, data management, and communications functions in the event of an unexpected complete outage of the primary power system. Use of emergency batteries for extended periods is impractical. Therefore, the primary power system shall be designed to provide at least half its normal output under any credible emergency conditions.

**A**

**7.300 ENVIRONMENTAL CONTROL/LIFE SUPPORT (ECLS)**

**7.301** The ECLS system shall control the SOC pressurized environment to the values indicated in Table 1.

**7.302** The ECLS will use regenerative concepts to minimize the resupply penalty of expendables. Table 2 defines the ECLS nominal design loads. Peak loads not listed are TBD.

**7.303** The cabin  $O_2$  shall be supplied by electrolysis of water.

**7.304** Nitrogen shall be supplied by catalytic reduction of hydrazine or from cryogenic nitrogen storage in the logistics module. A

**7.305** Oxygen shall be reclaimed from the  $CO_2$  by a  $CO_2$  reduction process.

**7.306** A regenerative  $CO_2$  removal system which concentrates the  $CO_2$  for further processing shall be provided.

**7.307** Contingency repressurization gas shall be provided to repressurize either Habitat Module one time or any normally pressurized module independent of any other module. Contingency repressurization gas shall be resuppliable as necessary by normal crew rotation and resupply operations.

**7.308** Urine shall be processed by a concept incorporating a phase change to produce water that is acceptable for water electrolysis and is potable.

**7.309** Wash water and humidity condensate may or may not be processed by a phase change concept, but must be adequately processed to ensure sterility and suitability as body cleansing water.

**7.310** The ECLS system temperature control shall maintain any selected temperature,  $\pm 2^\circ F$ , between the values indicated in Table 1 within the heating or cooling capacity of the system. When heating or cooling loads are high, the extreme range of temperatures shown in Table 1 are allowed.

**7.311** Provisions will be made to prevent objectionable and noxious odors emitted in any location from being transmitted to any habitable location in the SOC.

**7.312** The atmospheric constituents, including harmful airborne trace contaminants and odors, will be monitored and controlled in each pressurized habitable volume.

**7.313** As a design goal, atmospheric leakage of each module should be less than 0.5 lb/day with a maximum of 5 lb/day for the SOC pressurized volume.

**7.314** Overboard gas venting is permitted. Vents shall be nonpropulsive.

**7.315** Particulate matter filtration shall be provided in the ECLS for removal of particles above 300 micron size.

**7.316** The concentration of microbial count in the environment of each of the pressurized compartments containing crew quarters, process laboratories, or experimental facilities shall be monitored and controlled.

**TABLE I**  
**ECLS PERFORMANCE REQUIREMENTS**

Parameter	Units	Operational	90 Day Acceptable*	21 Day Emergency
CO <sub>2</sub> Partial Pressure	mmHG	3.8 max	7.6 max	12 max
Temperature	°F	65-75	60-85	60-90
**Dew Point Temperature	°F	40-60	35-70	30-75
Ventilation	ft/min	15-40	10-100	5-200
Wash Water	lb/man day	40 min	20 min	0
Potable Water	lb/man day	---	---	---
<b>A</b> ***O <sub>2</sub> Partial Pressure	psia	2.73-2.93	2.66-3.05	2.30-3.05
<b>A</b> Total Pressure	psia	11.8 ± .2	11.8 ± .4	9.0-14.7
Trace Contaminants	---	****24 hr. ind. st'd.	****8 hr. ind. st'd.	****8 hr. ind. st'd.
Maximum Crew Number	per SOC	8	8	12
Maximum Crew Number	per Habitat Module	4	8	8

**A** \*Acceptable level is adequate to meet a "fail operational" reliability criteria.

\*\*In no case shall relative humidities exceed the range of 25-75%.

**A** \*\*\*In no case shall the O<sub>2</sub> partial pressure exceed 25.9% or be below 2.3 psia.

\*\*\*\*hr. ind. st'd. = hour industrial standard.

**TABLE 2**  
**ECLS DESIGN AVERAGE LOADS**

		PEAK VALUES
Metabolic O <sub>2</sub>	1.84 lb/man day	3.65 lb/man day
Leakage	5.00 lb/day total SOC	
EVA O <sub>2</sub>	1.22 lb/8 hr EVA	3.19 lb/8 hr EVA
EVA CO <sub>2</sub>	1.48 lb/8 hr EVA	3.87 lb/8 hr EVA
Metabolic CO <sub>2</sub>	2.20 lb/man day	4.41 lb/man day
Drink H <sub>2</sub> O	4.09lb/man day	A
Food preparation H <sub>2</sub> O	1.58lb/man day	A
Metabolic H <sub>2</sub> O production	0.76 lb/man day	
Clothes wash H <sub>2</sub> O	27.50 lb/man day	
Hand wash H <sub>2</sub> O	4.00 lb/man day	
Shower H <sub>2</sub> O	8.00 lb/man day	
EVA H <sub>2</sub> O	9.68 lb/8 hr EVA	
Perspiration and respiration H <sub>2</sub> O	4.02 lb/man day (total condensate)	5.82 lb/man day
Urine H <sub>2</sub> O	3.31 lb/man day	
Food solids	1.60lb/man day	
Food H <sub>2</sub> O	1.10 lb/man day	
Urine solids	0.13 lb/man day	
Fecal solids	0.07 lb/man day	
Sweat solids	0.04 lb/man day	
EVA wastewater	2.00 lb/8 hr EVA	
Charcoal required	0.13 lb/man day	
Metabolic sensible heat	7000 BTU/man day	14,000 BTU/man day
Hygiene latent H <sub>2</sub> O	0.96 lb/man day	
Food preparation latent H <sub>2</sub> O	0.06 lb/man day	
Experiments latent H <sub>2</sub> O	1.00 lb/day	
Laundry latent H <sub>2</sub> O	0.13 lb/man day	
Wash H <sub>2</sub> O solids	0.44%	
Shower/hand wash H <sub>2</sub> O solids	0.12%	
Vehicle heat leak and non-ECLS thermal loads	TBD	
Air lock gas loss	2.40 lb/EVA	



**7.317** Capability shall exist for dumping module(s) atmosphere overboard in the event of module contamination or fire.

**7.318** Crew related consumable resupply shall be sized for 90 days based on the 24-hour nominal man use rate. A 90-day reserve of consumables shall be provided against the possibility that the normal resupply cycle is interrupted.

**7.319** The hydrogen contained in the ECLS subsystems shall not cause an explosive hazard if suddenly leaked into the cabin atmosphere.

**7.320** ECLS subsystems using or producing hydrogen shall preferably be located in the service module. Passing hydrogen lines through docking or berthing interfaces shall be avoided as a design goal.

**7.321** The ECLS system shall be designed so that major power consuming subsystems will use their maximum power draw on the light side of the orbit.

**7.322** 10KW of electrical power shall be provided to the pressurized emergency habitation volumes for crew survival up to a minimum of 21 days in LEO.

## **7.400 EXTRAVEHICULAR ACTIVITIES (EVA)**

**7.401** The maximum EVA duration will be eight hours/crewman/24-hour day. This 8 hours is in addition to 30 minutes each of pre- and post-EVA operations (suit donning/doffing, airlock ingress/egress).

**7.402** EVA consumable makeup resupply capability shall be based on 24 eight-hour EVA's per week as a minimum. Backpack recharge  $O_2$  shall be supplied by the electrolysis of water.

**7.403** No "pre-breathe" shall be required before EVA. EVA suit pressure will be 5.75 psia pure oxygen.

**7.404** The SOC shall provide two EVA airlocks. (The orbiter airlock is a satisfactory configuration.)

**7.405** The capability for a variable controlled rate of depressurization and repressurization of the EVA airlocks is required. The nominal rate is not to exceed 0.1 psi/sec. The emergency rapid depressurization and repressurization is not to exceed 1 psi/sec. Depressurization control should be possible from inside and outside the SOC as well as from inside the airlock. Repressurization control shall be possible from both inside the SOC and inside the airlock. Life support umbilical connectors shall be available outside the airlock.

**7.406** A capability to save airlock gas shall be provided. The resultant pump down pressure shall be 2.0 psia or less and shall take no longer than 15 minutes. A capability for using the airlock as a hyperbaric chamber at 3 atmospheres and operating the airlock without the pumping system for emergency EVA/IVA shall be provided.

**7.407** Provisions for EVA preparation, EVA equipment storage, recharge, checkout, maintenance and post-EVA activities shall be made in the airlock or in an adjacent pressurized compartment.

**7.408** A window shall be placed close to the airlocks to allow an observer to have visual contact with an EVA astronaut immediately after he has left the airlock.

**7.409** Voice communications and visual surveillance of EVA crew shall be provided.

**7.410** Translation means will include hand rails/hand holds and by MMU.

**7.411** Hand holds, hand rails, and restraint attach points must be provided along all EVA routes and at each EVA hatch.

**7.412** Locomotion, restraint devices and portable EVA workstations will be included in the external SOC design.

**7.413** EVA shall consider use of:

- . Saws, Files, Shears
- . Miter Box
- . Debris Control
- . Drills, Reamers, Hole Saws, Punches
- . Clamps, Wrenches, Riveting Tools, Pin Expansion Tool

- . Welders—Electron Beam, Spot, Seam
- . Fusing, Reduction Heating Coil
- . Snap Lines, Measuring Rods
- . Optical Surveying Systems (Rangefinder, Transit)
- . Gages, Measuring Tapes
- . VOM, Discontinuity Meters
- . Valve Actuation Handles
- . Leak Detection Gear
- . Cleaning Wipes

**7.414** The SOC design shall provide for simultaneous EVA of two crewmembers during Phase I and up to four crewmembers during Phases II and III.

**7.415** A minimum of two manned maneuvering unit support stations shall be provided during Phases II and III.

## **7.500 DATA MANAGEMENT**

**7.501** SOC status information shall be available as follows:

a. To the ground to confirm the existence of a safe, habitable environment and functional capabilities of critical life sustaining and operational subsystems prior to manning. Limited status information shall be available directly to the orbiter when the orbiter is docked or station-keeping with the SOC.

- b. Periodically to the ground for long-term trend analysis, logistics planning, etc.
- c. Continuously to the ground during critical or emergency operations.
- d. Onboard for:
  - 1) SOC subsystem status and caution and warning display.
  - 2) Control of EVA/IVA activity.
  - 3) Control of local logistics (e.g., crane operations, construction operations).
  - 4) Support of day-to-day operations planning.
  - 5) Malfunction analysis.

**7.502** System and mission status will not necessarily be transmitted to the ground on a real-time basis, but real-time capability shall exist.

**7.503** The data management subsystem serves as the central executive authority and coordinates the following functions:

- a. Data recording management
- b. Telemetry format selection
- c. Subsystem status display monitoring and configuration selection
- d. Consumables management
- e. Automatic fault detection and annunciation
- f. Mission hardware and free-flyer support
- g. SOC operation planning and control support
- h. Data processing management
- i. On-board command control

**7.504** The Space Operations Center data management and software system shall employ distributed processing. The distributed concept has been selected in order to associate software elements as closely as possible with the hardware elements they serve, to minimize software development problems, and maximize the final software flexibility effectiveness. The Space Operations Center includes several modules and subsystems, each of which will

include associated processing and software. Because of the need for an integrative function, a hierarchical approach, rather than an equal-authority distributed approach, has been selected.

A further important consideration in the data management and software system design is the recognition of the significance of interfacing with the on-board crew through controls and displays, and interfacing with external sources of data and commands, such as ground mission control and other flight systems. Subsystem designs will incorporate processor/controllers to perform independent data processing. Processor functions will include engineering units conversion, limit checking control of output stimuli, data formatting, communication with other subsystem processor elements, and support overall redundancy management.

**7.505** The data bus architecture for SOC subsystems management shall allow communication between any subsystems that need to exchange data without dependence on other elements or subsystems. The overall system structure shall mimic the hardware work breakdown structure to the extent necessary to maintain close association between software and hardware elements.

The system shall include a Space Operations Center main processor in each habitability module. One of these will be active and the other will serve as on-line backup. This processor will interface with the remainder of the systems through a data bus system. The data management system shall employ a primary and backup data bus or functionally similar architecture that provides redundancy and workaround provisions consistent with SOC safety and reliability requirements.

**7.506** Data management processing functions will be organized into microprogrammed entities. These entities may be physically packaged within a single LRU or separated into individual packages.

**7.507** Processor memories, arithmetic capabilities, word sizes and operational speed shall be commensurate with the function to be supported. Inter-system data transfers will be performed exclusively by an input/output interface compatible with the data bus network design.

**7.508** Integration of the subsystem processing elements requires a level of controlled functional interfaces via an ICD type specification. Such management techniques must be evaluated to minimize costs for hardware/software design, verification and operational maintenance. It is a design goal that all processors and mass storage media shall be compatible software-wise, such that the various processors can back one another up.

**7.509** Design of various data processing data transfer elements will incorporate transient error detection and recovery techniques. The design techniques will be compatible with the individual element's functional criticality. Processing functions critical to SOC integrity, crew safety, or SOC-shuttle interactions shall be accessible to ground command and shall not be impaired by loss of cabin pressure.

**7.510** Vehicle mass memory storage will be provided by the data management function. Mass memory will store subsystem application programs and overlays, have callable maintenance and checkout routines, maintain crew display formats, provide buffering for ground/vehicle communications, and other to-be-defined storage requirements. Design will ensure integrity and separation of individual subsystem data sets.

**7.511** Operational instrumentation format selection and control of recording is a function of data management. Each individual subsystem processor is responsible for gathering the

appropriate instrumentation parameters, preprocessing them and transferring the necessary data sets to the data management processor.

**7.512** A data bus network/hierarchy shall be employed for all intra/inter subsystem transfers of digital data and shall employ a standard interface module in all devices connected to the bus.

**7.513** A fiber optic data bus, employing the NASA developed multiwavelength monolithic terminal, shall be considered as a baseline for system study purposes.

**7.514** The network architecture and protocol shall accommodate system expansion without impact on existing capabilities. Data traffic thruput loading and system LRU interfaces shall provide a minimum of 50% expansion at the design data rate.

**7.515** Inputs for vehicle operations will be manually and/or automatically initiated. The execution of such operations will be via a computer controlled output.

**7.516** To minimize weight, power, volume, and logistic requirements; the concept of integrated controls shall be the design goal. Dedicated controls/switches will be minimized. Functions such as system power application and distribution may require dedicated switches.

**7.517** A standard, modular input control medium shall be employed for subsystem interfaces to achieve functions such as subsystem mode selection, computer input controls, and vehicle attitude and configuration management. Voice entry, programmable function keys, or CRT touch entry are typical design candidates.

**7.518** Positive or advisory feedback of control operations shall be available to the operator. Critical/hazardous operations shall employ arm/fire type sequence commands.

**7.519** Crew displays shall include caution/advisory discrete event lights and multifunction, programmable CRT's. Color, aural, and flashing techniques will be employed to ensure crew attraction. Caution and warning and anomaly information shall be provided from the subsystems, and from the station instrumentation data management, and caution and warning data shall be distributed to the controls and displays and the communications subsystem for crew annunciation.

**7.520** CRT's (or equivalent technology) shall employ color displays to enhance presentation of information and crew interaction. Displays will present alpha-numerics, graphics, and vector symbology. The integrated CRT display system shall provide programmable roll-in/roll-out formats to permit crew flexibility and accessibility to all vehicle subsystem parameters, graphic representation of vehicle trajectories, attitude and functional configuration.

**7.521** The integrated entry and display system will employ tutorial and interactive techniques to accomplish vehicle control, on-board checkout/maintenance, and mission operations. Design concepts to minimize printed text documents and which enhance zero "g" crew operations are highly desirable. The SOC shall maintain an adequate archive for mission operations support, planning, and procedures, as well as for crew entertainment and for data bases for system and subsystem maintenance and emergency operations procedures.

(Note: numbers 7.522 - 7.549 are reserved for future additions to general data management requirements)

**7.550** ~~Specific Processing Requirements~~—Note: following are functional requirements and one not intended to specify a particular architecture. Functions 7.551 through 7.560 are applicable to the initial SOC. Functions 7.561 through 7.567 are add-on capabilities to be provided as needed to support SOC missions.

**7.551** **SOC Main Processing.** The function shall provide overall station configuration management under crew supervision. In this sense, main processing shall provide high level commands, including override capabilities to the various subsystems or subfunctions. Examples include overriding the normal attitude and orbit management strategy for the flight control system issuing cabin temperature and pressure commands to the environmental control and life support system, and issuing emergency management commands to other subsystems.

The main processing function shall also serve as the primary processor for operations support and scheduling software, to provide day-to-day software and data management support to crew operations. It shall maintain the working archives on mission plans and procedures, project status, crew status, schedule status, and action and problem status.

**7.552** **Common Data Base.** The common data base shall be a random access memory, and shall provide multiple access to frequently used common data bases for the various processing functions. Depending on the size of the common data base, it may be necessary to back up the RAM with mass storage.

**7.553** **Station Instrumentation Data Management.** The SOC will include a set of instrumentation primarily concerned with measuring temperatures, pressures, consumables, quantities, and other items not associated with a specific subsystem. Instrumentation data management shall be on the data bus, and shall provide data to the common data base buffer as necessary, for access by the various subsystems and the SOC main processor. A path shall also be provided to route instrumentation outputs to the communications subsystem for direct relay to the ground.

**7.554** The data interface to the displays shall be formatted to minimize the processing requirements on other functions for interpretation or formatting displays. The displays processing function shall also access or receive, and transmit displays information to remote terminals such as those in the galley and in the crew private quarters, and shall format data and drive the control center CRT and digital displays.

**7.555** The communication system processing function shall orchestrate the operation of the communication subsystem and shall handle the interfacing of the SOC data management system with the outside world through the communication system, including communications with shuttle, orbit transfer vehicles, free flyers, ground (either directly or through the tracking and data relay satellite) navigation data from the global positioning system, and intra-SOC communications, including audio and caution and warning.

**7.556** The flight control subsystem shall determine the SOC state vector using information from the communication subsystem GPS nav data. The flight control system shall provide the normal attitude control and orbit management function. The algorithms shall be designed to maintain continuous attitude control either through utilization of orbit makeup thrusters or through utilization of attitude offsets to minimize or counter gravity gradients. System dynamics and adaptive control routines shall reside in this system. The flight control system will also control and command the CMG's (if used) and will issue thrust commands to the propulsion subsystem.

**7.557** The Environmental Control and Life Support System (ECLSS) processing function shall orchestrate the various elements of the ECLSS system (with suitable data exchange with the automated power systems management subsystem) in order to minimize battery draw-down by the environmental control and life support system, consistent with maintaining proper environmental control of the station. Each subelement of the environmental control and life support system such as the humidity control, water electrolysis, CO<sub>2</sub> removal, etc., shall have digital interfaces between the environmental control and life support processing function and local component microprocessing as necessary to control the proper operation of each component. The environmental control and life support system processing function shall also handle normal anomaly and emergency management for the environmental control and life support system including subsystem or element failures, atmosphere cleanup, pressure control, etc. These functions shall be overrideable by the crew through the command and display system and in addition, certain override functions may be provided by the SOC main processing function.

**7.558** The Automated Power Systems Management (APSM) processor shall control the solar array and battery systems for power management to minimize battery degradation. It shall maintain cognizance and provide data to the data bus on array status, battery status, power electronics status, any anomalies, emergencies or failures, and will provide emergency override and load leveling management of discretionary or optional loads such as some of those associated with cooking, lighting, etc.

**7.559** Propulsion processing shall monitor and maintain status of the propulsion system, distribute thrust commands to primary or secondary thrusters, detect failures or anomalies, determine and maintain status of propellant remaining, and provide data feedback on propulsion systems status and performance.

**7.560** An input/output buffer and formatter shall be provided to allow digital data transfer between the space shuttle and the SOC data management system.

**7.561** The Propellant Storage and Transfer system shall maintain status information on the cryogenic propellant storage and transfer systems and will provide the necessary control and management of propellant transfer operations, to include propellant gaging, pump operation, valve control, thermal management of cryogenic propellants, and status information input to the data bus.

**7.562** The Spacecraft and Project Test/Checkout processing function shall provide the principal interface to checkout and test of spacecraft or construction projects being conducted by the Space Operations Center. In many instances, it will be a conduit and formatter for data and stimuli exchange between ground-based computer and the system being checked out. It shall control the remote umbilical bus on the construction facility that interfaces with the spacecraft or other project being tested.

**7.563** The Orbit Transfer Vehicle Test and Checkout processing function shall provide a function similar to spacecraft and project test and checkout, but for the manned and automated components of the orbit transfer vehicle. It shall also interface with a data remote umbilical and shall interface with the computers on board the OTV and its manned capsule to effect test checkout and readiness analysis. It shall be connected to the main data bus to provide information to the command and control station. The design of this processing function shall be coordinated with design of the upper stage(s) it is to support, in order to eliminate unnecessary duplication of function.

**7.564** The Construction and Flight Support System processing function shall orchestrate and control the operation of the mobility system, the cherry picker system, and the mobile



remote work station system. Data connections between these systems may be by local RF link rather than by hardwired data bus as appropriate. This processing function shall accept crew commands from the controls and displays system or from a remote crew station, and translate these commands into commands to the individual elements of the construction system.

**7.565** The Mobility, Cherrypicker, and Mobile Remote Work Station processing functions shall translate higher level commands (such as move from here to there) into the individual motor or actuator drive commands necessary to cause the device to accomplish construction and flight support system commands. They shall include position detection and anti-collision algorithms insofar as is practicable, and shall also include control algorithms to suppress oscillations or spurious motions. In addition, the MRWS processing function, for the pressurized version, shall include all functions necessary to provide environmental control and life support in the MRWS.

**7.566** The health maintenance subsystem shall include a dedicated processor or functional equivalent to provide diagnostic and process instrumentation support for the health maintenance facility and other data base management, such as crew medical history archives. Requirements for medical data processing are discussed in more detail under section 4.2.

**7.567** An experiment support processing capability shall be available in the HM to provide support to SOC-based experiments. Software functional requirements are TBD.

## 7.600 COMMUNICATIONS AND TRACKING

**7.601** The communications and tracking subsystem shall be designed to provide C&T services between the SOC and various space vehicles interoperating with the SOC. These shall include the Space Shuttle Orbiter, EVA crew members, OTV's, freeflyers, remote teleoperators, relay satellites, and co-orbiting satellites. Link characteristics and performance requirements are shown in Table 3. A

**7.602** Duplex communications via a synchronous satellite relay system must be provided beginning with the initial manned flight.

**7.603** The normal SOC/ground uplink and downlink channels shall operate through a relay satellite at S-band, Ku-band, or millimeter-wave frequencies. The communication links between the SOC and orbiter shall operate at S-band frequencies. This links between the SOC and free-flyers and/or manned/unmanned OTV's shall be at S-band, Ku-band, or mm wave frequencies depending on equipment available on the other vehicles. A

**7.604** The communication system shall be capable of transmission, reception and processing of voice, telemetry, commands and wideband data, TV, and text and graphics (reference Table 3). The system shall include the capability for secure communications (including any COMSEC requirements), and shall operate in an RFI environment at all times under normal and emergency operating conditions. Special provisions shall be made for anti-jam (AJ) and spoofing protection. Relay of data to/from SOC shall be provided between the SOC and ground via a synchronous satellite. A

**7.605** Reception and processing of GPS (global positioning system) signals for the SOC navigation will be provided.

**7.606** The SOC Communication and Tracking will acquire and track augmented and non-augmented detached vehicles for the purposes of traffic control, rendezvous and docking and orbital ephemeris generations (reference Tables 3 and 4). It is a design objective to achieve 100% coverage within  $\pm 15$  degrees of orbital plane. Coverage for remainder of sphere shall be 75% or greater, except within 8 km of SOC where 100 percent coverage is a design goal for free-flyers having propulsive stages. A

The SOC tracking radars shall be capable of a whole-sky sweep for target acquisition at up to 2000 km range in 2 minutes. The tracking radars shall be capable of monitoring up to 10 targets. In order to minimize the need for whole-sky sweeps, the tracking radar shall be equipped with path prediction compactation capability so that in multiple-target monitoring mode the radars can be directed to each target sequence. The radar shall operate in long range and proximity modes. The long range performance goal is a range of 2000 km; range and velocity accuracies, 1 km and 1 m/sec; angular resolution, 25 mr. The proximity performance goals are: range, 100 km; range and velocity accuracies, 10m and 0.1 m/sec; angular resolution, 10 mr.

**7.607** The capability for voice conferencing shall be provided between up to 4 EVA crew, manned spacecraft, the ground network, and the SOC. The audio subsystem shall provide the capability to recognize, process, amplify, mix, synthesize, switch, and distribute voice to and from all internal user locations, hardline interfaces, and radio frequency interfaces.

**7.608** For each manned state of SOC buildup and operations, SOC-ground and SOC-manned spacecraft duplex voice communication capability shall be available from any pressurized volume the crew might retreat to when an emergency condition exists.

TABLE 3. SOC COMMUNICATIONS LINKS PERFORMANCE REQUIREMENTS

Link-SOC To/From	Frequency* Band	Number** of Vehicles	Range Requests	Data Requests
Relay Satellite	S, Ku, or mm	1	38000 km	Di-Rate/Low Rate Data, TV, Voice
Orbiter	S-band	2	2000 km	Voice & Data
EVA	Probably UHF	4	10 km	Duplex Voice; Low-Rate Data
OTV (Manned)	Ku-band or mm wave	2	38000 km - 2000 km - 100 km -	Voice, TLM, Low-Rate Data Ranging TV from OTV to SOC
OTV (Unmanned)	Ku-band or mm wave	2	38000 km - 2000 km - 100 km -	TLM, Low-Rate Data Ranging TV from OTV to SOC (remote piloting aid)
Free-Flyer	S-band, Ku-band or mm wave	4	2000 km - 100 km -	TLM, Low-Rate Data, Ranging TV from free-flyer to SOC
Tracking Radar	mm wave	Up to 10 targets	2000 km - 100 km -	long-range mode short range mode
GPS	L-band		18500 km	Navigation Data

\*Subject to Technology Developments.

\*\*Simultaneous communications requirement.

TABLE 4

## SOC RF COMMUNICATION LINKS OPERATIONAL REQUIREMENTS

SOC Comm	Usage	Interruptible	
To/From Relay Satellite	Continual When Targets are in the Coverage Volume of Interest	Yes	A
To/From Orbiter	Continual During Rendezvous Docking, Separation	Except During Docking	
To/From EVA	Continuous During EVA	No	
To/From OTV	Continual During OTV Launch and Recovery Operations	Except During Docking	
To Free-Flyers	Occasional (Operations, Orbit Maintenance, Recovery)	Except During Docking and Maneuvering	
From Free-Flyers	Continual (Status)	Yes	
Traffic Control	Continual When Targets are in the Coverage Volume of Interest	No	A

- 7.609** SOC attitude constraints shall not be required to maintain acceptable RF circuit performance margins.
- 7.610** SOC RF communication link operational requirements are shown in Table 4.
- 7.611** Simultaneous communication requirements with multiple elements are described in Table 5.
- 7.612** The SOC shall provide a communication link through the docking interface systems with the communications system of attached vehicles.
- 7.613** Internal communications (duplex voice, caution and warning signals, public address, closed circuit video and wireless voicecomm for crewman) shall be available in all habitable areas of the SOC including EVA airlocks, and all active docking ports. Internal communications shall not be interrupted nor degraded within the remaining pressurized volume due to a malfunction of a single or group of SOC modules. The capability to maintain voice communications while crewmen maneuver within and between modules shall be provided by an umbilical-free-system.
- 7.614** A common time element will be used by all system elements and/or time data will be included as part of each systems information.
- 7.615** Generation, processing, distribution, transmission, recording and reception of television, text and graphics signals shall be provided. Closed circuit TV shall be available for crew entertainment, support of docking, and/or special area monitoring. Ground commanded and crew initiated hard copy readout shall be provided.
- 7.616** Subsystem design shall include a built-in-test (BIT) capability to facilitate detection and reporting of functional discrepancies. As a minimum, this BIT capability shall enable failure detection at a functional path level in flight along with fault isolation. BIT will be implemented by utilizing continuously monitoring built-in-test-equipment (BITE), self-test circuitry, and by providing adequate test point information at the electrical interfaces.
- 7.617** All equipment will be capable of being maintained in a quiescent or powered-down configuration and reactivated by command channels from the SOC or ground.
- 7.618** For vehicles utilizing active rendezvous and docking systems the SOC will provide radar enhancement devices (RED) or active transponders. The RED's will provide passive point sources of high radar reflectivity. A
- 7.619** Generation, processing and telemetry transmission of narrowband and wideband engineering data shall be provided for ground analysis.
- 7.620** Generation, processing and telemetry transmission of subsystem operational data shall be provided by the Communications and Tracking System.
- 7.621** Planned and unscheduled maintenance shall be performed at the LRU level. LRU design shall facilitate replacement by SOC crewmen as a routine activity. Those LRU's mounted external to the habitable volume such as antennas, transmitters and receivers and TV cameras shall have EVA servicing provisions.

**TABLE 5**  
**SIMULTANEOUS SOC COMMUNICATION LINKS**

SOC Comm To/From	Relay SAT	Orbiter	Simultaneous Elements			GPS
			EVA	OTV	Free Flyer	
Relay Sat		X	X	X	X	X
Orbiter	X		X		X	X
EVA*	X	X		X	X	X
OTV	X		X		X	
Free Flyers*	X	X	X	X		X
GPS	X	X	X	X	X	

\* Multiple-TBD

X-Indicates Simultaneous Operations

**7.622** The communications and tracking (C&T) system shall interface with the integrated entry and display system via C&T processor/controller(s). The C&T processor/controller(s) shall provide status monitoring, automatic configuration management, fault isolation, and all necessary display/control functions for operations.

**A**

**7.623** The overall communications and tracking reliability requirements will be met through long-life design, scheduled maintenance and repair, and redundancy.

**7.700 DOCKING/BERTHING**

**7.701** Docking is defined as the joining in space of two spacecraft or spacecraft modules by maneuvering one into contact with the other, at the docking interface, using reaction control thrusters.

**7.702** Berthing is defined as the joining in space of two spacecraft or spacecraft modules by maneuvering one into contact with the other, at the berthing interface, using a manipulator.

**7.703** Provide at least two locations for Orbiter docking. One location shall allow nominal operations of crew transfer and logistics. The other may allow for crew transfer only. The two locations shall also allow two Orbiters to be in the docked position at the same time and provide safe docking maneuver clearance for either Orbiter without reconfiguring the SOC.

**7.704** The Orbiter docking systems shall be designed to allow docking at 90 degree alignment increments about the respective axis.

**7.705** Berthing ports and hatches shall be sized for a nominal 40-inch diameter opening. The 40-inch diameter opening shall be "D" shaped (same as or similar to orbiter airlock and aft cabin bulkhead hatches) to allow the hatch to be passed through the opening.

**7.706** All hatches shall be capable of operation from either side of the hatch.

**7.707** Capability for equalization of pressure across the hatch shall be provided.

**7.708** All hatches shall close in direction of positive pressure differential.

**7.709** All hatches shall be provided with hinge linkages to control hatch motion.

**7.710** Areas into which hatches open shall be designed so that the full open position of the hatch does not block crew passage.

**7.711** All pressure hatches shall have a window.

**7.712** All umbilical interconnections shall be within the pressurized environment, if that service to be interconnected is generally routed within the module's pressurized environment. Any service interconnection made outside of the pressurized volume shall be automated but shall be maintainable by EVA. Internal interconnections may be automated and/or manual.

**7.713** Docking systems and berthing systems shall be androgynous, except for certain specialized umbilical interconnects (i.e., modules with identical docking systems may be docked together, and modules with identical berthing systems may be berthed together).

**7.714** Impact load attenuation and alignment subsystems of both berthing systems and docking systems must be designed to be commensurate with the mass properties of the module on which it is installed.

**7.715** All berthing ports on the SOC basic configuration shall be geometrically identical, except for specialized umbilical interconnects, such that any module of the SOC may be berthed to any berthing port -- other configuration factors permitting.



**7.716** The SOC berthing ports and the Orbiter's docking system, located on its docking module, shall be designed such that the Orbiter may dock to any SOC berthing port, with the provision that the Orbiter's docking system is "active" (i.e., providing for impact load attenuation, energy absorption, and capture latching). This assumes that proper physical clearances exist, and that the dynamics associated with the system mass properties for this situation are reasonable.

**7.717** All active functions of the berthing systems and docking systems (i.e., impact attenuation, capture latching, structural latching, etc.) shall normally be performed by one side with the other side in a passive mode. Either side shall be capable of all active functions with the other side in a passive mode. However, it may be that the best engineering choice for certain berthing ports is to make that port totally or partially passive.

**7.718 Docking-design impact conditions**

Axial closing velocity	0.16-0.50 ft/sec
Lateral velocity	0.2 ft/sec
Angular velocity	.6 deg/sec
Lateral misalignment	0.75 ft
Angular misalignment	5.0 deg. roll
	6.0 deg. pitch/yaw

The above data are total values relative to the docking interface.

**7.719 Berthing-design impact conditions**

Closing velocity, fps	0.05 ft/sec
Lateral velocity, fps	0.05 ft/sec
Angular velocity, deg/sec	0.1 deg/sec
Lateral misalignment, ft	0.2 ft
Angular misalignment, deg	3 deg roll
	3 deg pitch/yaw

**7.720** Docking/berthing equipment shall not require removal for crew or equipment transfer.

**7.800 FLIGHT CONTROL/PROPULSION**

**7.801** The GN&C system shall have the capability to provide targeting parameters for the SOC powered flight function and for thrusting maneuvers of detached modules.

**7.802** The GN&C system shall have the capability of commanding the desired thrust vector direction for powered flight and issuing on/off thrusting commands.

**7.803** The GN&C system shall have the capability of automatically determining the SOC's state vector to an accuracy compatible with GPS operation. A state vector update capability from ground tracking is also required.

**7.804** The GN&C system shall have the capability of propagating the state vector along a coasting trajectory for up to 10 days to an accuracy consistent with rendezvous trajectory and other mission planning requirements.

**7.805** There shall be onboard tracking and orbital ephemeris generation capability for detached modules under SOC control.

**7.806** The attitude control system (ACS) shall provide three-axis control torques to counter external and internal disturbances, maintain stabilization of the various flight modes, and effect attitude maneuvers for reorientation of the SOC and/or control system desaturation. Control torques shall be provided by momentum exchange devices and a reaction control system.

**7.807** The SOC must be stabilized for initial manning and buildup.

**7.808** Stabilization and control will be provided by the SOC during construction and assembly of large structures.

**7.809** Attitude control requirements for experiments in excess of those required for normal operations may be provided by a separate stabilization and control system.

**7.810** The capability of maintaining stability when moving large masses or constructing appendages shall be required. Additional stabilization devices may be needed for this capability.

**7.811** The ACS shall provide stabilization and control of the thrust axis during translation maneuvers. Translation maneuvers are required during all phases of the buildup.

**7.812** The nominal flight orientation will be a flight mode to minimize the accumulation of momentum from aerodynamic and gravity gradient torques. Nominal attitude control accuracy will be  $\pm 5$  degrees at TBD deg/sec.

**7.813** The ACS shall be capable of stabilizing the configuration to  $\pm 0.3$  degrees and 0.005 deg/sec for docking (including assembly).

**7.814** The RCS shall provide control forces capable of meeting three-axis attitude hold, attitude maneuvers, and CMG desaturation and translation such as orbit maintenance requirements during all phases of SOC assembly and operations, including docked operations with the orbiter.

**7.815** Controlled deorbit capability shall be provided in the SOC propulsion system. (Refer to requirements 2.030 - 2.032) Thrust available for controlled deorbit shall be a minimum of 4000 newtons (900 lb).

**7.816** The propulsion system shall maintain a 90-day propellant reserve margin for orbit makeup, beyond the planned resupply time, under worst-case atmosphere density conditions (solar max, 3 sigma) during all states of building and operation.

**7.817** The RCS shall be an LRU design.

**7.818** The RCS thrusters shall be located in such a manner as to provide minimum cross coupling effects.

**7.819** The RCS thrusters should be located to minimize plume impingement effects on SOC mission hardware or orbiter structures.

**7.820** Thruster size shall reflect an optimum compromise between required attitude control authority, minimum total impulse thruster state-of-the-art, redundancy, orbit maintenance requirement, and interaction with other attitude control devices such as CMG's.

**7.821** SOC RCS propellant is baselined as monopropellant hydrazine. Other options are to be evaluated, including a gaseous  $H_2 - O_2$  system integrated with a regenerable fuel cell electrical power system.

**7.822** SOC RCS thrusters assuming hydrazine propellant shall be catalytic spontaneous decomposition type.

**7.823** Thruster location optimization shall be provided such that orbit maintenance and CMG desaturation can be accomplished simultaneously with the same propellant.

**7.900 CREW SUPPORT**

**7.901** The SOC shall be capable of operating in both single and multiple shift modes.

**7.902** In general, day-to-day planning of activities shall be performed onboard; long-range planning shall be performed on the ground.

**7.903** Crew transfer from the Orbiter to the SOC (manned or unmanned) shall be performed in a shirtsleeve environment.

**7.904** Routine evaluation of crew health shall be performed onboard. Medical care will be provided by trained crewmen (at least to paramedic level). Emergency patients will be transferred to the ground (also see 4.200).

**7.905** The SOC shall accommodate a mixed male-female crew.

**7.906** Crew systems shall be designed using the 5th and 95th percentile male and female NASA astronaut anthropometrics adjusted for 30 year growth trends.

**7.907** The initial SOC shall be sized to accommodate at least four crewmen.

**7.908** Provisions for double occupancy will be made for exchange crew overlap periods. The maximum crew size will be eighteen crewmen for 14 days (8 SOC crewmen + 8 replacement SOC crewmen + 2 Orbiter crewmen).

**7.909** There is no requirement that the SOC configuration provide artificial gravity for the crew.

**7.910** During SOC operation a minimum of two separate pressurized habitable volumes with independent life support capability and habitability provisions for a nominal crew of eight for 90 days will be provided. During the early stages of SOC buildup, the system should provide habitability provisions for four crewmen for 90 days.

**7.911 Lighting**

a. Control Panels and Task Areas: 538-1076 lx (50-100 ftc) adjustable - selectable (with auxiliary 200 ftc spotlight, if required). Suitable for machining, inspection of small details, drafting and small, delicate operations.

b. Habitat Areas: 215-538 lx (20-50 ftc) adjustable - selectable. Suitable for reading and general office work.

c. General Areas: 108-205 lx (10-20 ftc). Suitable for normal activities such as kitchen, washroom, passageways and storerooms.

d. Contingency: 22-54 lx (2-5 ftc). The SOC shall have an emergency lighting system in all passageways and compartments so that the crew can proceed toward appropriate evacuation ports in an emergency. The electrical power source for the emergency lighting shall be batteries which are kept fully charged by the electrical power system. In the event of loss of electrical power, the emergency lighting shall switch on automatically.

e. Portable Lighting: Portable flashlights and lanterns shall be strategically stored in specific locations for use during maintenance, repair, and emergencies.

**7.912** The SOC shall provide non end-to-end systems operations simulations for onboard flight crew training.

**A**

## **8.000 FLIGHT SUPPORT FACILITY**

**8.001** The SOC shall have the capability to assemble all elements of a space vehicle from their individual berthed positions to the final launch configuration. It is anticipated that propulsion stages (e.g. OTV) will be fueled under conditions for which this requirement applies. Offloading of propellants into SOC storage will also be required. **A**

**8.002** Standoff distances for the operation of OTV main propulsion and RCS shall be commensurate with those for the STS.

**8.003** The SOC shall provide berthing capability for up to four elements of space vehicles awaiting assembly at any given time.

**8.004** The SOC shall provide access to all berthed elements of a space vehicle for inspection, maintenance, and servicing activities.

**8.005** The SOC shall provide continuous unobstructed IVA access to the crew cabin of an MOTV while docked.

**8.006** Cryogenic OTV's and crew modules stored at the SOC shall be provided meteoroid/debris collision protection and passive thermal control by a suitable hangar. The hangar shall incorporate work platforms, necessary equipment, utilities umbilicals and lighting for maintenance tasks. **A**

**8.007** The SOC shall provide the capability of transferring propellants from the Shuttle Orbiter to SOC storage and then to the stage(s) of an OTV or directly from the Shuttle Orbiter to the OTV.

**8.008** The SOC shall provide necessary maintenance, monitor, and checkout equipment for interfacing with the manned OTV onboard checkout system for verifying OTV systems status. The capability to telemeter data to the ground via the SOC shall be provided.

**8.009** The SOC shall provide the capability to perform final verification and checkout of space vehicle payloads.

**8.010** Specialized payload related checkout equipment shall be provided by the payload.

**8.011** Standard power, mounting, and similar provisions are to be provided by the SOC.

**8.012** The SOC shall be capable of controlling the launch of manned OTV's via communications with ground-based control, autonomously with SOC-based control, or in support of OTV crew control. For unmanned OTV's, launch control shall be via communications with ground-based control or SOC-based control.

**8.013** The FSF shall incorporate an OTV transportation system at such time as this becomes necessary for stage or payload handling.

**8.014** FSF vehicle and payload handling provisions shall minimize scar-type design penalties on the vehicles and payloads.

**8.015** Provide unpressurized storage locations for space-based OTV replacement parts (ballutes, engines, avionics modules). The necessity of protective enclosures for these elements will be defined on an item-by-item basis. **A**

**8.016** EVA will be the primary mode of operations for vehicle maintenance with the exception of crew module interior equipment. **A**

**8.017** EVA operations shall be suspended during vehicle launch and returning vehicle capture. **A**

**8.018** Orbit transfer systems which are based at or operate from the SOC will consist of expendable and reusable systems operating in both manned and unmanned modes. The systems will be performing delivery and retrieval missions for a large variety of payloads which operate in orbit from LEO to Geosynchronous Earth Orbit (GEO) at various inclinations. These systems will also provide delivery capability for planetary payloads. Specific requirements are as follows. **A**

Capability to perform rendezvous and proximity operations with the SOC.

Capability to accept both SOC and ground commands. Commands during proximity operations shall be from the SOC.

Capability for systems being safed from SOC prior to berthing with SOC.

Capability for providing safe separation distance prior to launch.

Compatibility with SOC berthing, handling device, and deployment mechanisms.

Compatibility with SOC propellant loading equipment.

Compatibility with SOC checkout and maintenance equipment.

Compatibility with SOC utility services.

Compatibility with SOC plume impingement criteria.

Space based orbit transfer systems with GEO capability shall be designed such that they can be upgraded for manned operations.

**9.000 CONSTRUCTION FACILITY**

**9.001** The growth SOC construction facility shall be capable of deploying, assembling, and fabricating large spacecraft structures.

**9.002** The construction facility shall be capable of installing on the structures all subsystems required for complete, operational space systems. These subsystems shall include, but not be limited to, electrical power, thermal control and heat rejection, propulsion and attitude control, guidance and stabilization, communications and tracking, data management, mechanical systems, and specialized subsystems peculiar to a specific space system or mission.

**9.003** The construction facility shall be capable of calibrating installed subsystems and shall be capable of checking out the operation of the completed system prior to release from the SOC.

**9.004** The SOC shall be capable of releasing the fabricated space system, attaching propulsion modules and initiating the launch of the system to its operational orbit.

**9.005** The SOC shall provide the following for the construction-related functions:

Electrical power:	3 kW continuous 6 kW peak
Communications	TV, audio, data
Illumination:	TBD Lumens/m <sup>2</sup> over TBD area
Stabilization:	0.1 deg/sec 0.01 deg/sec <sup>2</sup>
EVA:	a maximum of 24 eight-hour EVA's per week
Data management:	TBD bps
Information storage:	TBD bits
Material storage:	TBD m <sup>3</sup>

**9.006** When positioning and assembly operations are to be performed using EVA, on EVA work station and aids shall be available to assist in final positioning of parts/subassemblies.

**9.007** The growth SOC CF shall accommodate construction of spacecraft that include the following characteristics:

a. Rectangular Structures - The construction facility shall be capable of constructing rectangular platform structures up to 80m wide and 480m long with a maximum mass, including subsystems, of TBD kg.

b. Parabolic Antennas - The construction facility shall be capable of constructing paraboloidal antenna structures up to 100m in diameter, with a maximum mass, including subsystems, of TBD kg.



c. Cylindrical Structures - The construction facility shall be capable of constructing spacecraft with cylindrical shapes of up to 100m diameter.

**9.008** The construction facility shall be capable of maintaining the alignment of the fabricated structure within TBD cm per meter.

**9.009** Fabrication and assembly activities should be isolated from crew habitations to reduce noise and other disturbances.

**9.010** Collision avoidance software and/or maximum torque override shall be incorporated in manipulators and other supporting equipment.

**9.011** SOC design should provide direct visibility from the command center for a large portion of the construction zone, particularly in the high activity areas where fabrication and EVA is being performed.

**9.012** The CF shall provide a transporting system for the mobile cherrypicker.

**9.013** The SOC must provide a structural system for attaching construction fixtures.

**9.014** The growth SOC must provide a support/indexing fixture system that can be readily reconfigured to adapt to a variety of spacecraft configurations. This system shall minimize the need for spacecraft dedicated fixtures. This fixture system to include the following elements:

- o Structural building block modules
- o Standard docking interface accessory for turntable/tiltable
- o Beam support/indexing modules

**9.015** The SOC must provide a construction support equipment storage system. (See Section 12.000)

**9.016** The SOC must provide an umbilical system that can be reconfigured to adapt to the variety of spacecraft. This umbilical system will provide electrical power, command/control signals TV and audio and test/checkout signals conductors and fluid and gas delivery lines.

**9.017** Provisions shall be made for dissipation of waste heat generated during space processing, manufacturing, and assembly operations.

**9.018** Debris shall not be released as the result of any construction operation.

**9.019** The operational SOC must provide a construction fixture that can be attached to the turntable/tiltable that can be readily adopted to a variety of spacecraft configurations.

**9.020** The operational SOC CF must be capable of handling spacecraft that may be as large as can be transported in the Orbiter cargo bay. Construction operations will include deployment of appendages, test and checkout, and mating to an OTV.

## **10.000 SATELLITE AND MISSION SERVICING FACILITY**

**10.001** The SOC shall provide capabilities to service non-propulsive co-orbiting/LEO propulsion/GEO propulsion free-flyer satellites, onboard science and applications missions, attached mission modules, and shall provide basing for manned or automated OTV satellite servicing missions as appropriate. **A**

**10.002** SOC capabilities for free-flyer servicing shall include means for crew visits to nearby satellites within the safe operational capability of manned maneuvering units or manned teleoperators, and shall include the capability to temporarily berth free-flyers for service. **A**

**10.003** Maneuvering of free-flyers to the near vicinity of the SOC shall be under the control of the SOC. For such maneuvers, a zone of collision risk shall be established. Final maneuvering to berthing within the zone of collision risk shall be under the control of a crewperson operating a maneuvering unit or teleoperator. **A**

**10.004** For servicing of satellites with contamination-sensitive instruments, either the SOC shall be capable of operation during the servicing period without thruster firing or sensitive instruments must be covered. During such periods, attitude control shall be maintained by a combination of gravity gradient stability and CMG's. This requirement does not imply that the SOC will be a precision instrument pointing platform.

**10.005** Experimental equipment and experiments shall be accommodated by the SOC on a space-available basis. Such experiments may be attached to berthing ports (e.g. tether-type experiments) or may be accommodated within the pressure volume of the SOC. Potential locations include the habitat and service modules and the docking tunnel. Interior walls of these modules, not occupied by permanently-installed SOC equipment, shall be designed for installation of equipment racks and shall provide access to electrical and data services at reasonable spatial intervals. As a general guide, it shall be assumed that all experimental equipment intended for use within the SOC pressure volumes shall be designed to pass through the inter-module hatches. Further, such equipment shall conform to all SOC safety requirements.

**10.006** The SOC shall be designed to provide services including thermal control, electrical power, data bussing, and ventilation to a dedicated experiment module. Such a module has not been defined by the SOC system definition studies. It may be assumed that the general nature and quantities of these services will be similar to those provided the Spacelab by the shuttle orbiter.

**10.007** One function of a dedicated experiment module may be to carry out experiments too hazardous for conduct within the SOC. Accordingly, the interface services between the SOC and an experiment module shall include the capability for immediate termination of ventilation services and all electrical power services except emergency lighting, and rapid crew egress, hatch closure, and module depressurization.

**10.008** OTV basing requirements for satellite servicing are included under the flight support facility requirements (Paragraph 8.000 et seq). Manned OTV crews shall be accommodated by the SOC habitats as necessary to avoid special Shuttle flights for crew delivery or return to Earth. As this accommodation will generally be for short periods, it may exceed the nominal SOC crew number of eight.

Table 6

**SOC SATELLITE SERVICING FACILITY REQUIREMENTS**

**o Satellite Retrieval/Access**

- A** o Rendezvous
- o Despin
- o Destruct
- o Capture
- A** o Docking/Berthing
- o Power Down
- o Disarm
- o Demate from OTV
- o Appendage Stow
- o Return Satellite to Earth

**o Operations and Maintenance**

- o Install/Remove/Transfer
  - o Subsystem Components
  - o Subsystem Modules
  - o Payload Modules
  - o Payload Pallets
  - o Samples
  - o Film
- o Fluid and Gas Transfer
  - o Propellants (Cryo, fluids, gasses)
  - o Payload Samples
  - o Thermal Control Fluids
- o Calibrate Instruments
- o Extend/Retract/Replace/Reposition/Jettison Appendages
- o Clean Optical Surfaces
- o Visual Inspection/Observation
- o Telemetry and Command
- o Conduct In-Situ Experiments
- o Data Retrieval
- o Photography
- o Manual Override
- o Apply Coatings
- o Focus Instruments/Optics
- o Maintenance
  - o Inspect
  - o Checkout
  - o Fault Diagnosis
  - o Repair Components/Modules
    - o Reshape Structural Members
    - o Splice Wires
    - o Tape Holes and Rips
    - o Repair Fluid System Leaks
    - o Repair Frozen Mechanical Joints

**Table 6**

**SOC SATELLITE SERVICING FACILITY REQUIREMENTS  
(Continued)**

- o Attach Thermal Control Coverings
  - o Repair Electrical System
  - o Repair Corrosion
  - o Fabricate Replacement Parts
- o Align
- o Store Replacement/Removed Components/Modules/Payloads
- o Maintain/Resupply ECLSS Components/Consummables
- o **Satellite/Deployment**
  - o Deploy Appendages
  - o Power-Up
  - o Checkout
  - o Mate to Propulsion Stage
  - o Release
  - o Monitor
  - o Control Satellite/Transportation Vehicle Until Beyond SOC Control Zone

- A 10.009** Satellite servicing functions and equipment shall be common with satellite preparation, checkout, and construction equipment to the degree practicable. Further, it is a program objective that this equipment be an evolutionary development from shuttle-based satellite servicing equipment. A representative list of functional capabilities is presented in table 6.
- A 10.010** The SOC control center shall provide controls and displays for satellite test and checkout.
- A 10.011** Provisions shall be made to store satellite replaceable equipment.
- A 10.012** The FSF shall provide on area, services and equipment for handling, servicing, refueling, and storing propulsion stages (e.g., POM and VSS).
- A 10.013** Manipulators shall be provided for berthing and maneuvering satellites on SOC.
- A 10.014** Handling and Positioning Aids shall be provided to berth and hold satellites for servicing.
- A 10.015** OCP shall be available for EVA use during satellite service operations.
- A 10.016** Means shall be provided to allow satellite payload operations control center participation in satellite test and checkout.
- A 10.017** The FSF shall incorporate a transportation system to move satellites and service equipment from one service area to another.
- A 10.018** An MTV shall be provided for inspection of satellites (attached or unattached) beyond the reach of manipulators.
- A 10.019** Provisions shall be made to store satellites awaiting repairs, propulsion stage, or scheduled maintenance and checkout.

**11.000 GENERAL PURPOSE OPERATIONS SUPPORT EQUIPMENT (GPOSE)**

**11.001** The SOC shall include a complement of general-purpose operations support equipment as necessary to support its missions. A preliminary list of representative equipment is presented in Table 7.

**11.002** The approach for development and provisioning of GPOSE shall be (a) to identify needs for specific equipment items on the basis of ongoing and past operational experience; (b) to maintain commonality with similar equipment used by the Shuttle to the extent practicable; (c) to deliver GPOSE to the SOC on resupply flights as it is needed; and (d) to provide accommodation for this equipment onboard the SOC as necessary to avoid transporting it between Earth and the SOC because of storage space limitations.

**11.003** All equipment shall be provided with restraints or tethers as necessary to prevent accidental release.

Table 7

**General Purpose Support Equipment**

- o Mobile cherrypicker with open manned remote work station.
- o Lighting
  - o Fixed-Flood Lights, Spot Lights
  - o Portable-Flood Lights, Spot Lights
- o Photographic Cameras-Still and Movies
- o Closed Circuit Television-Fixed and Handheld Cameras
- o EVA Systems
  - o EVA Suits (minimum of 4)
  - o EVA Tools
    - o Saws, Files, Shears
    - o Miter Box
    - o Debris Control
    - o Drills, Reamers, Hole Saws, Punches
    - o Clamps, Wrenches, Riveting Tools, Pin Expansion Tool
    - o Welders-Electron Beam, Spot, Seam
    - o Fusing, Reduction Heating Coil
    - o Snap Lines, Measuring Rods
    - o Optical Surveying Systems (Rangefinder, Transit)
    - o Gages, Measuring Tapes
    - o VOM, Discontinuity Meters
    - o Valve Actuation Handles
    - o Leak Detection Gear
    - o Cleaning Wipes
  - o Portable EVA Work Station
- A** o Mobile Cherrypicker Accessories
  - o Small Object Handling Tool
  - o Large Object Handling Tool
  - o Turntable/Tilttable
  - o Umbilical System
- A** o Mobile Platform with Twin Manipulators
  - o Snare End Effector
  - o Open Cherrypicker

**Table 7**

**General Purpose Support Equipment  
(Continued)**

- A**
  - o   Handling and Positioning Aid
  - o   Open Cherrypicker



## **12.000 STORAGE FACILITY**

**12.001** The SOC shall incorporate an external storage facility. The purpose of this facility is to avoid transportation costs of transporting equipment between Earth and the SOC and to avoid using the Shuttle Orbiter as a warehouse.

**12.002** The storage facility shall be designed for evolutionary growth corresponding to growth in mission needs. Initially, the storage facility shall provide storage for general-purpose, construction, and satellite or flight support servicing equipment not conveniently stored internally to the SOC pressure modules. An example is a mobile remote work station (MRWS). It is anticipated that the facility will grow to the capability to accommodate an entire Shuttle payload in addition to SOC mission support equipment. The SOC/storage facility arrangement shall not preclude growth to accommodate more than one Shuttle payload.

**12.003** The storage facility shall be designed to minimize or eliminate payload and equipment design features solely for storage attachment.

**12.004** The storage facility shall be lighted as necessary to allow the crew to utilize the facility during occulted periods. This requirement shall be met by general-purpose lighting to the extent practical, with a minimum of dedicated lighting.